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WATER RESOURCES REPORT

Hamakua Area Agricultural Water Study

UNITED STATES DEPARTMENT OF AGRICULTURE
Economics, Statistics, and Cooperative Service
Forest Service
Soil Conservation Service

STATE OF HAWAII
Department of Land and Natural Resources
Mauna Kea Soil and Water Conservation District

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WATER RESOURCES REPORT

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Prepared by:

United States Department of Agriculture
Soil Conservation Service
Honolulu, Hawaii

August 1980

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INTRODUCTION

Purpose and Scope

The primary purpose of this report is to inventory the existing water resources in the study area and to identify potential sources of water that could be feasibly developed for agricultural purposes. Data from this report and other special reports will be used to develop alternative solutions to the agricultural water problems in the area as identified in the Plan of Work.

This report covers the occurrence, quantity and quality of water resources, and a brief description of existing water distribution systems. Relationships of rainfall and geologic formation to occurrences of ground water and surface water resources are described. In local meetings, ranchers and farmers in the area indicated a need for agricultural water in the high elevations [3,000 feet (900 m) to 7,000 feet (2,100 m)] of Waimea, Ahualoa, Paauilo, and Honokaa. Therefore, identification of agricultural water sources was limited to the higher elevations to reduce pumping costs.

Numerous other studies on water resources within the general study area, done by federal, state, and county agencies and the private sector, will be reflected in this report.

Geographical and Historical Setting

The study area (Fig. 1), lying on the northeasterly portion of the island of Hawaii, is bounded by Waipio Valley to the north, Laupahoehoe to the south, the Pacific Ocean to the east, and the Mauna Kea Forest Reserve boundary to the west. The area encompasses approximately 211,660 acres (85,720 hectares). The northerly and westerly boundaries are straddled by the Kohala Mountains [elevation 5,500 feet (1,700 m)] and Mauna Kea Mountain [elevation 13,796 feet (4,205 m)] respectively.

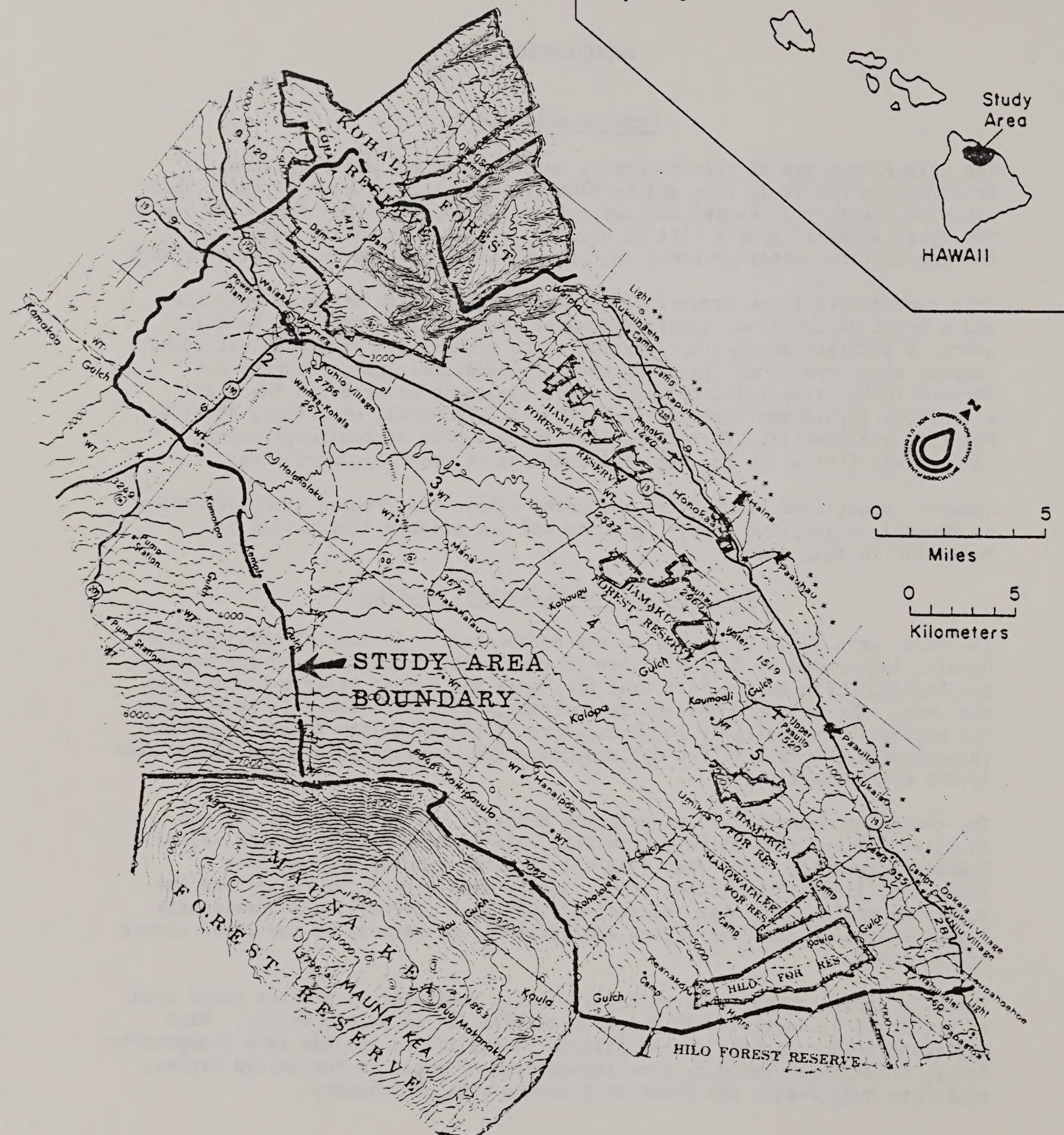
The two major communities, Kamuela and Honokaa, are 58 miles (93 km) and 43 miles (69 km) respectively from Hilo, the economic center of the island. Kamuela [elevation 2,800 feet (850 m)], a rural farming and ranching community, lies in the Waimea Plains saddle area between Mauna Kea and the Kohala Mountains. Honokaa [elevation 1,000 feet (300 m)], a predominantly sugar-plantation community, lies southeasterly of Kamuela on the lower slopes of Mauna Kea.

Hawaii's agricultural industry had its early beginning within the study area as evidenced by ancient taro and rice cultivation in Waipio Valley. With sugarcane's introduction to the islands in the 1780's and the 1876 Reciprocity Treaty which permitted duty-free importation of sugar to the United States, sugarcane cultivation and processing became a major industry.

m = meters

km = kilometers

LOCATION MAP



LOCATION MAP

Hamakua Area Agricultural Water Study Hamakua, Hawaii

Figure 1

After the introduction of cattle by Captain Vancouver to the island of Hawaii in 1793, King Kamehameha I hired John Parker to round up all the cattle in the Waimea area. This marked the beginning of the cattle industry within the area and eventually led to the formation of Parker Ranch, which today is the largest cattle ranching operation in Hawaii.

These early agricultural operations and subsequent truck farms, orchards, small ranches, and eventual urbanization have placed a burden on the water resources during drought periods. The earliest major attempt to harness water resources in wet areas of Kohala Mountains to service water-short areas for agricultural purposes was the construction of the Upper and Lower Hamakua Ditches in 1910. These systems tapped the abundant water resources in the Kohala Mountains and transported it via ditches to the sugarcane fields along the Hamakua Coast. Since that time, the State Department of Land and Natural Resources (DLNR) constructed the Lalamilo Irrigation System and Parker Ranch has installed a stockwater system, both of which derive water from the Kohalas.

Climatic Conditions

The climate within the study area is characterized by moderate variations in annual temperature (Fig. 2) and drastic variations in average annual rainfall from one location to another (Fig. 3) together with a prevailing northeast tradewind.

Both the relative constant length of daylight period and the slight variation in the altitude of the sun in Hawaii result in moderate variations in annual temperature [40°F (4.4°C) to 74°F (23.3°C)] from one location to another. Temperature is primarily a function of elevations and records show that mean temperature decreases at an approximate rate of 1°F for each 300 feet (1°C for each 160 m) increase in elevation, the rate being somewhat greater at lower elevations.^{1/} This constant rate of decrease exists up to approximately 5,000 feet (1,500 m) to 7,000 feet (2,100 m) elevations, at which point there is a temperature inversion or reversal and this rate subsequently decreases. This inversion serves as a ceiling for the tradewinds.

The rainfall variations are mainly due to the topography, tradewinds, and temperature. As moisture-laden tradewinds from the northeast ascend the slopes of the Hamakua Coast, they are cooled and release most of their moisture by elevation 3,000 feet (900 m). Annual rainfall varies from 60 inches (1.5 m) along the coastline to 100 inches (2.5 m) at elevation 3,000 feet (900 m) and then decreases to 20 inches (.5 m) at the southerly boundary (Fig. 3).

The ceiling or temperature inversion at 7,000 feet (2,100 m) forces the tradewinds around Mauna Kea [elevation 13,796 feet (4,205 m) and over the

^{1/} Hawaii State Department of Land and Natural Resources, An Inventory of Basic Water Resources Data, Island of Hawaii, Report R34, page 83.

Waimea Plains; whereas the lower Kohala Mountains [elevation 5,000 feet (1,500 m)] allow the moisture-laden tradewinds to flow over them and thus result in the high rainfall belt in that area with a peak of 175 inches (4.4 m) annually. Conversely, the tradewinds are blocked by the high peaks of Mauna Loa and Mauna Kea in the Laupahoehoe and Ookala areas and this results in a high rainfall belt also, with a peak of again 175 inches (4.4 m) annually.

Geology

The Kohala Mountains were formed by a series of lava flows: (1) Pololu Volcanic Series during the Pliocene Age, and later (2) the Hawi Volcanic Series (Fig. 4).

The Pololu Series, with a relatively high rate of weathering, is predominantly olivine basalt; whereas, the Hawi Series is made up of andesite and trachyte. This latter series forms a cap on the mountain and is separated from the basaltic rock by a layer of soil and erosional unconformity.

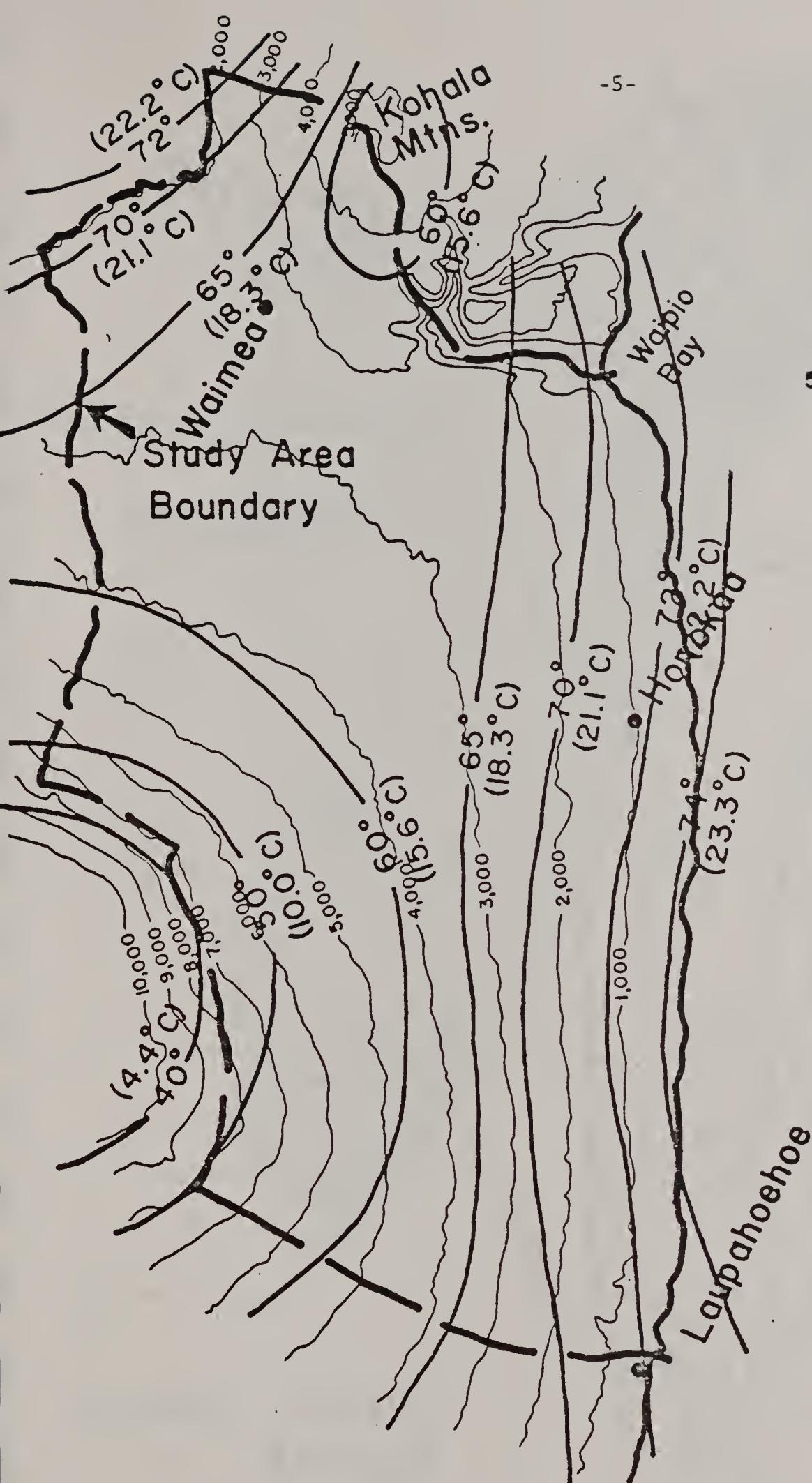
The Pololu Series is highly permeable, while the andesitic flows of the Hawi Series are poorly permeable except in clinkers. Perched water is found in the soil base under the Hawi flows. Impermeable dikes, which intersect the tributary canyons of Waipio, are found mostly in the Pololu Series. These dikes impound water in high elevations, and release them through springs that have been exposed by the erosive streams.

Mauna Kea and the Hamakua Coast within the study area are composed of mostly volcanic rock with small amounts of alluvium present and occur in the following series: (1) Hamakua Volcanic Series and (2) Laupahoehoe Volcanic Series (Fig. 4).

The Hamakua Series, basically composed of basalt and andesite, is moderately to highly permeable and contains basal ground water along the coast. At higher elevations, soil and ash beds perch small amounts of water.

The Laupahoehoe Series consists of the upper and lower members. The lower member, composed of andesitic and basaltic lavas, has poor to moderate permeability and contains some perched water on ash or dense flows; whereas, the upper member is moderately to highly permeable, but yields no water.

Pahala Ash on the slopes of Mauna Kea is an accumulation of pyroclastic debris that is found mostly on the Laupahoehoe Series. Perched water occurs in this ash only in areas where it lies upon a denser lava.



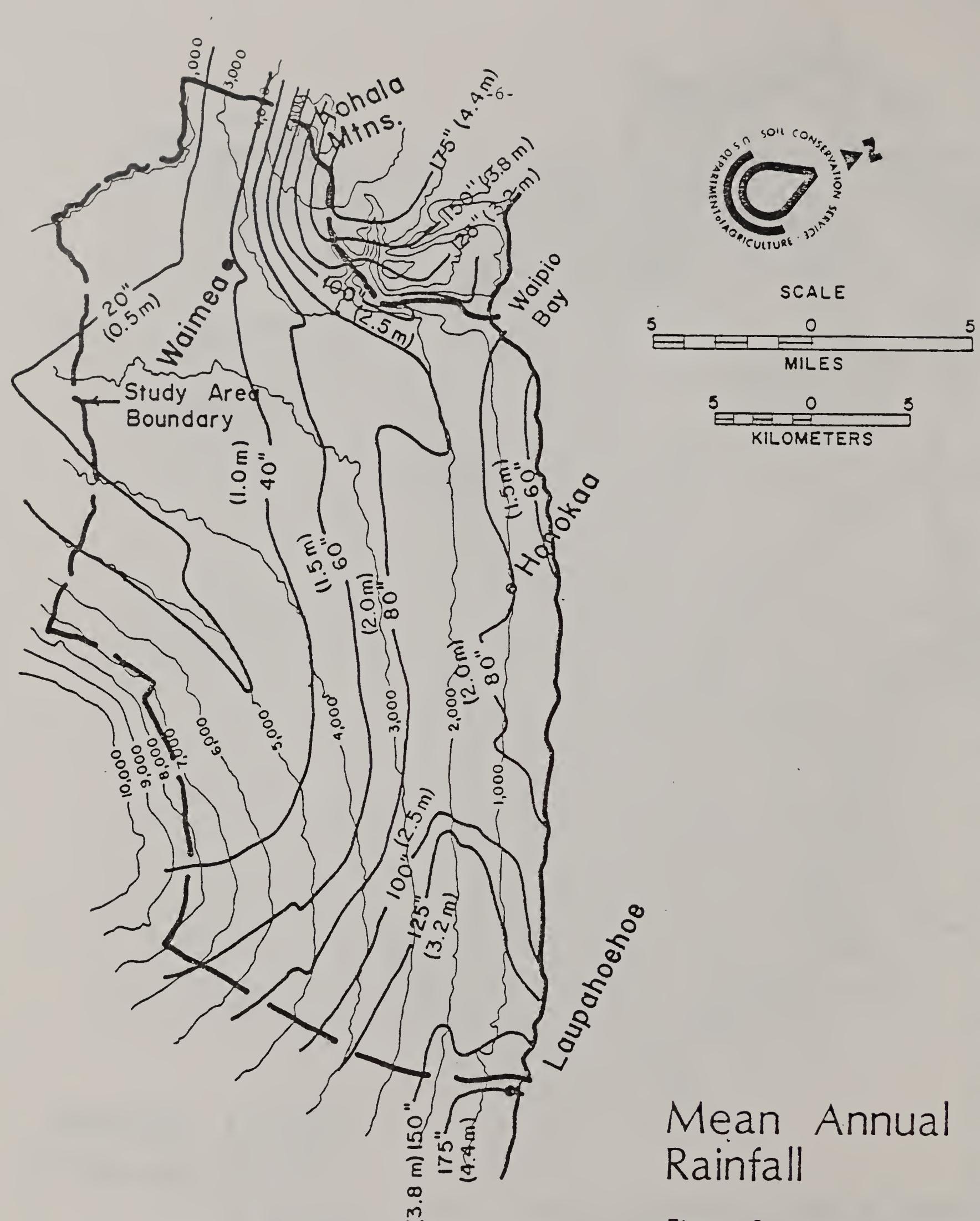
SCALE

C - Centigrade
F - Fahrenheit

Mean Annual Temperature °F

Source: An Inventory of Basic Water Resources Data:
Island of Hawaii Report R34
State of Hawaii, DLNR

Figure 2



Mean Annual Rainfall

Figure 3

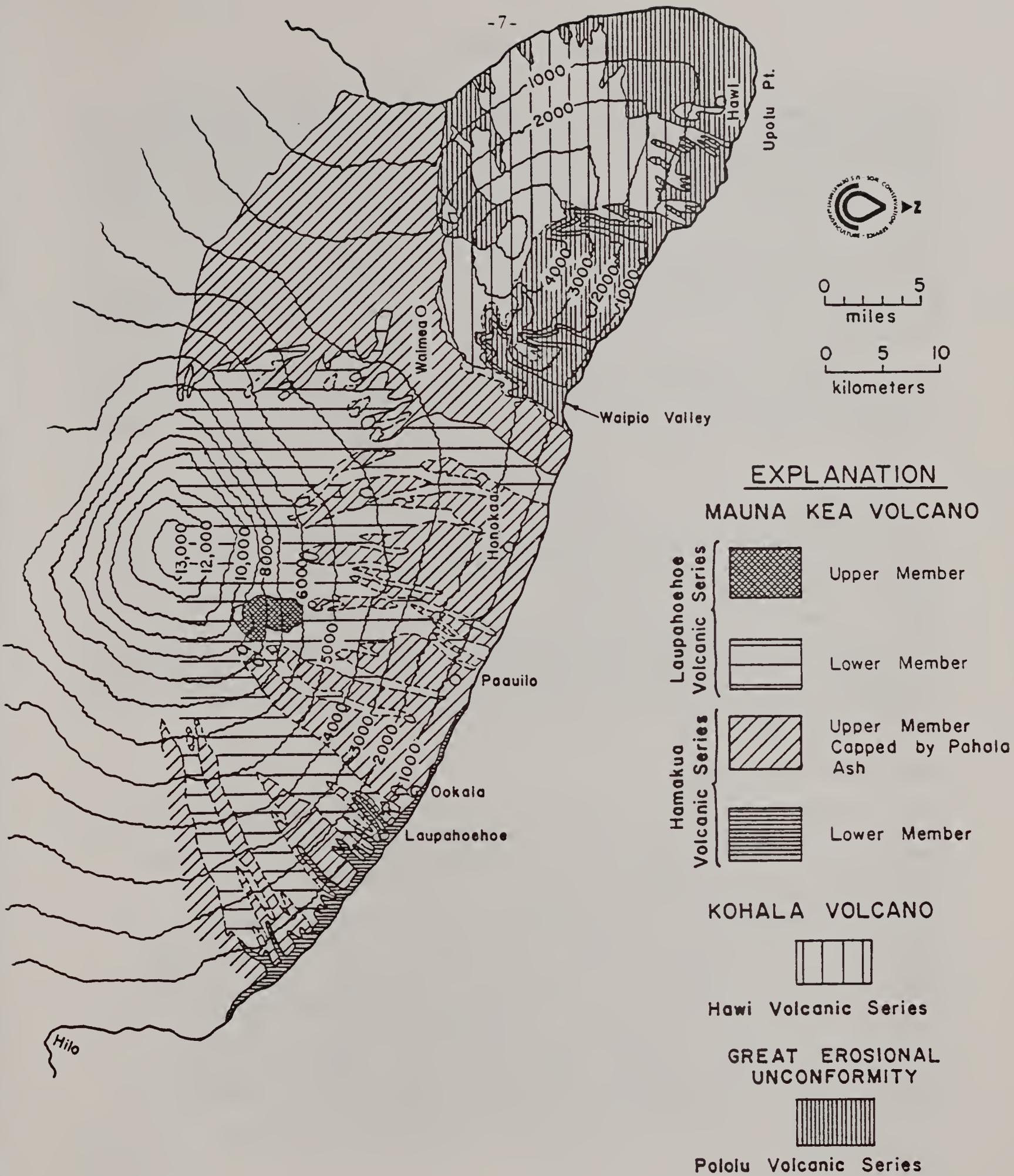


Figure 4 -Generalized Geologic Map of Kohala Mountains and Mauna Kea

Source: Preliminary Report On The Water Resources Of Kohala Mountains And Mauna Kea
State of Hawaii DLNR Circular C14

WATER RESOURCES

An inventory of the available water resources in the area must be made in order to identify the potential sources of agricultural water that can be feasibly developed. Previously, water resources have been inventoried in study reports by U.S. Geological Survey (USGS) and DLNR. Among these reports are: "Preliminary Report of the Water Resources of the Kohala Mountains and Mauna Kea, Hawaii," by USGS and "A Water Development Plan for South Kohala - Hamakua, Island of Hawaii," by DLNR. The former report, which encompassed this study area, was an inventory of the quantity and quality of water resources available for development; whereas the latter, using this data, outlined various development plans to develop water in the Kohala Mountains. Both these reports will be used as a basis to identify potential sources of agricultural water.

Water resources occur basically in three modes: runoff, ground water flux, and evapotranspiration. The major concern of this report is the occurrence and quantity of the first two. Figure 5 shows the annual disposition of water resources in relation to their respective Hydrographic Areas I and II.

Surface Water

Important considerations in determining suitability of streams as potential water sources are: elevation, stream characteristics such as magnitude and annual flow duration, and proximity to demand area. In examining the annual rainfall pattern (Fig. 3), two areas of high rainfall emerge as possible sources of water; namely the Kohala Mountains and Laupahoehoe. Both areas have an average annual rainfall of 175 inches (4.4 m); however, streams in the Laupahoehoe area are basically intermittent and may not be feasible for development due to distances and elevations involved. Therefore, only the streams in the Kohala Mountains are suitable sources of water and are considered in this report.

Streams and Stream Gages

Of the streams in the Kohala Mountains, the ones on the southern flank are the most promising sources of water. Their high elevations [3,000 feet (900 m) to 4,000 feet (1,200 m)], close proximity to the demand areas and their abundant flow throughout the year make them desirable.

Eight major streams include the Kawainui, Kawaiki, Alakahi, Waikoloa, Kohakohau, Hauani, Koiawe and Waima Streams (Fig. 6). Of these, only the former six will be considered as possible sources of water for this study since the Koiawe and Waima Streams are fairly inaccessible and lack stream flow data. All of these streams, except for Hauani and Kohakohau are perennial with average annual flows varying from a maximum 8.8 million gallons per day (MGD) (33,312 m³/D) for Kawainui Stream to a minimum of a .9 MGD (3,558 m³/D) for Hauani Stream. Although the annual yield of the Hauani Stream is relatively low with no flow during 4.3 percent of the time, it has been included in this discussion as a possible source of water.

The Kawainui, Kawaiki, Alakahi, Koiawe, and Waima Streams originate in the high, swampy and wet areas of the southeastern slopes of the Kohala Mountains and flow into Waipio Valley; while the Waikoloa, Kohakohau and Hauani Streams originate in the forest reserve on the southwest slopes of the Kohala Mountains, flow toward Waimea Town and reach the ocean only during high sustained rainfall.

Since 1901, the USGS has maintained a network of stream and crest gages to measure stream runoff (Fig. 7). As a result of the USGS report of 1963 mentioned earlier, gages (Fig. 6 and Table 1) were installed on the Kawainui (#16720000), Kawaiki (#16720300) and Alakahi (#16725000) Streams along with the Upper Hamakua Ditch (#16720500 and #16724800). These stream gages together with already existent gages at Waikoloa (#16758000), Kohakohau (#16756000) and Hauani (#16759000) Streams served as a comprehensive stream monitoring system in the Kohala Mountains for this study.

Periods of records for these stream gages ranged from 10 years for Kawaiki Stream to 31 years for Waikoloa Stream. Common period of record for all six gages was from 1969 to 1978, and their locations were in the higher elevations [Kawainui - 4,060 feet (1,257 m) to Hauani - 3,117 (950 m)]. There are no stream gages on the Koiawe and Waima Streams.

Available Surface Water

The total surface water available from the streams can be estimated by analyzing the existing gage data. Gage data retrieved from the USGS Water Storage (WATSTOR) data bank in Reston, Virginia, for the six gages included:

1. Lowest mean value of discharge and ranking for the one, three, seven, fourteen and thirty consecutive days.
2. Number and percent of zero-value days.
3. Normal monthly means (all days).
4. Statistics (mean, variance, standard deviation, skewness, coefficient of variation, percentage of average value) on normal monthly means.
5. Normal annual means (all days).
6. Statistics on normal annual means.
7. Ranking of normal monthly means and percentile.
8. Ranking of normal annual means and percentile.

This data, although not presented in this report, is available for technical evaluation.

Monthly yields were developed for each stream gage for their entire period of record by multiplying the normal monthly means (or mean discharge) from the WATSTOR data by the respective number of days in the month. These values have been tabulated in Appendix A-1 to A-6 and can be used in the reservoir operation or water budget analysis. Although the standard expression for yield is acre-feet, million gallons has been used for this study due to conventional useage.

However, the total water developed so far is not indicative of the amount that can be safely diverted from these streams. Minimum stream discharges must be maintained to insure: (1) a balance in the stream eco-system and (2) a sufficient water supply for any downstream users. Presently, minimum stream discharge standards are being developed for the State of Hawaii by DLNR under the State Water Resources Functional Plan. Further, maximum discharge that can be diverted from individual streams will depend on the design capacity of the diversion system that will be developed as part of this study. Thus, in order to determine the maximum and minimum divertable discharges, flow duration curves for the six streams and the Upper Hamakua Ditch (Appendix B-1 to B-10) were developed from WATSTOR data.

Frequency Analysis

Yield from streams can also be expressed as a function of percent probability (percent chance equal to or greater than) and is usually computed using the "method" presented in Hydrology Study - A Multipurpose Program from Selected Probability Distribution Analyses by W. H. Sammons, TP-148. This served as the methodology in developing monthly and one-day lowest mean frequency distribution data for gages in combination or individually.

Assuming that water will be diverted from a combination of either (1) the upper three streams (Kawainui, Kawaiki and Alakahi Streams) or (2) all six streams (Kawainui, Kawaiki, Alakahi, Kohakohau, Waikoloa and Hauani Streams), respective monthly yields were added for their common period of records (1969 - 1978) and frequency distributions were developed for both combinations of streams (Appendix A-7 to A-10). Monthly frequency distributions were also developed for individual streams for both their entire period of record and their common period of record. Although these have not been presented in this report, they are available for use.

Irrigation from direct diversion of available stream flow is dependent upon the magnitude of the one-day lowest mean yield that occurs during the highest months of consumptive use (June, July and August). As a result, the lowest one-day mean yield was retrieved from the WATSTOR data and frequency distributions were developed during the critical months for a combination of the upper three streams (Appendix C-1 to C-3).

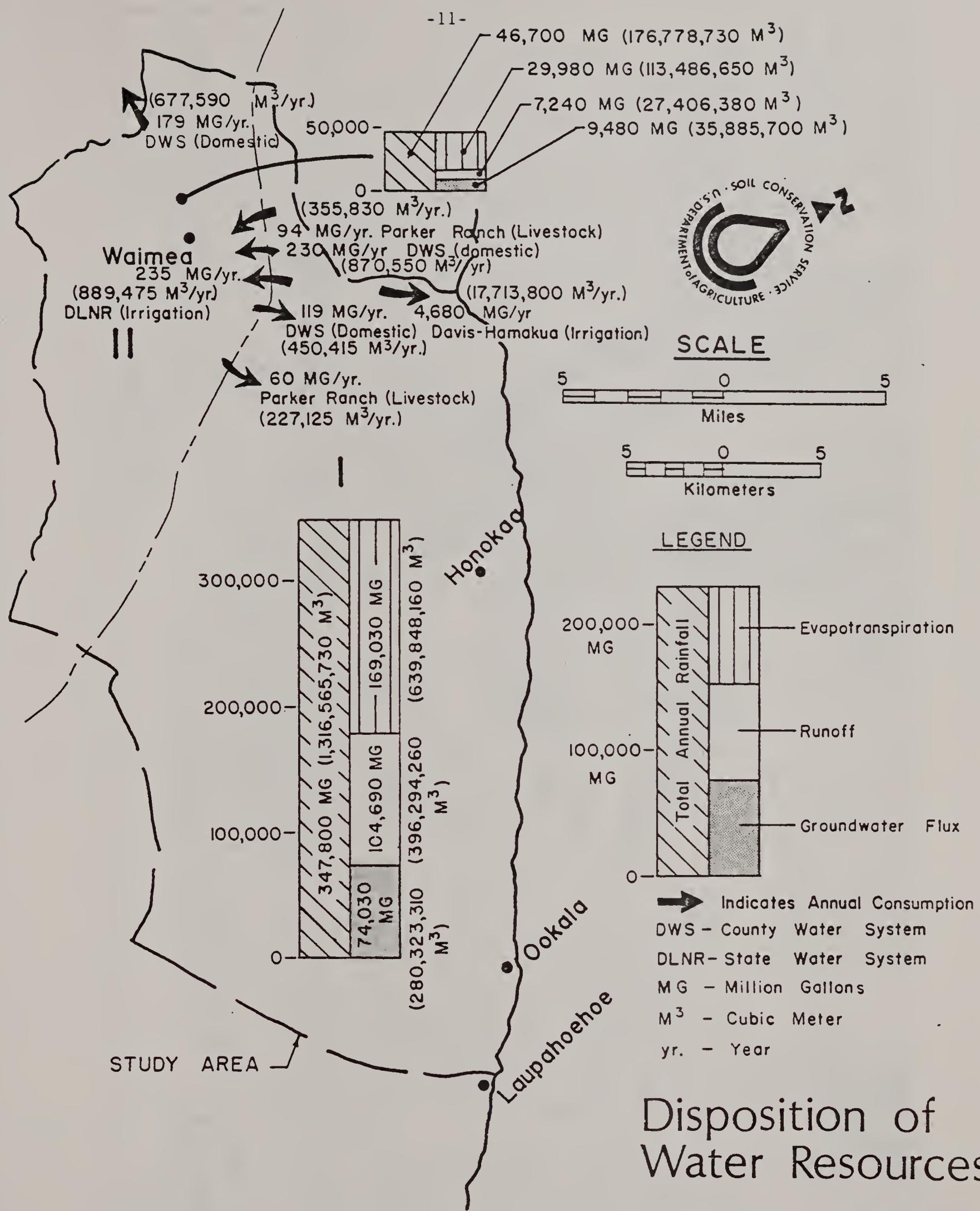


Figure 5

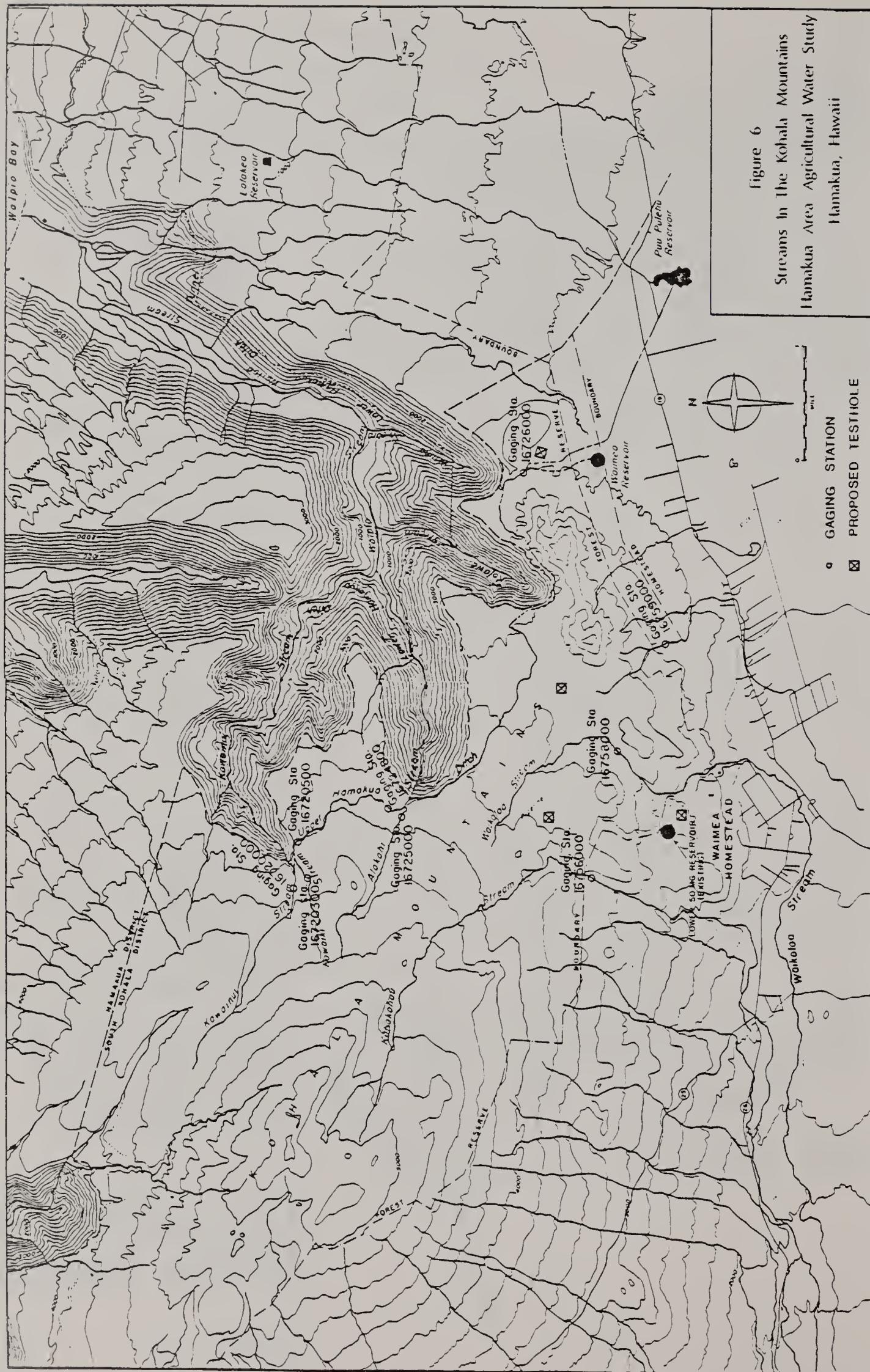
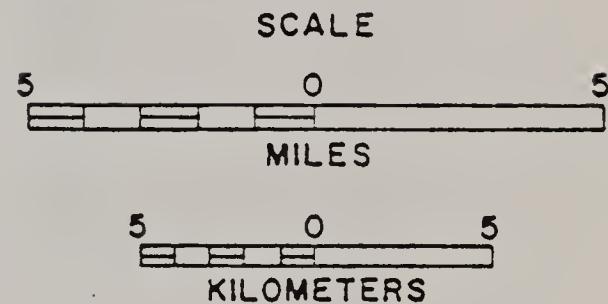
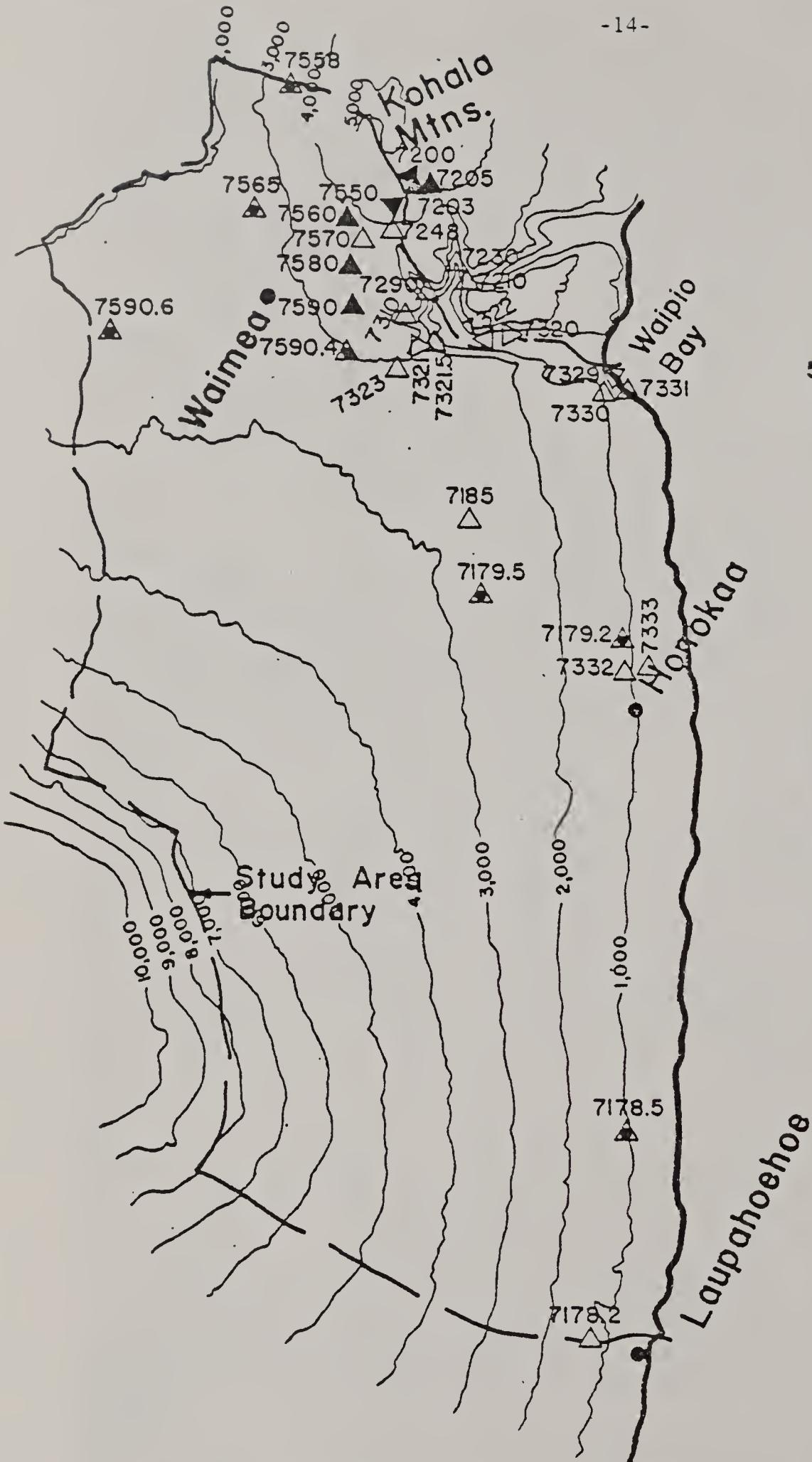


Figure 6
 Streams in The Kohala Mountains
 Hamakua Area Agricultural Water Study
 Hamakua, Hawaii

TABLE 1
STREAMFLOW GAGING STATIONS
HAMAKUA AREA AGRICULTURAL WATER STUDY

GAGE NO.	GAGE NAME	ELEVATION FT. (m)	RAINAGE AREA mi ² (km ²)	YEARS OF RECORD	DISCHARGE			REMARKS
					MAXIMUM MGD (m ³ /d)	MINIMUM MGD (m ³ /d)	AVERAGE MGD (m ³ /d)	
16720000	Kawaihui Stream near Kamuela	4,060 (1,237)	1.58 (4.09)	14	1,551 (5,871,174)	.01 (.38)	8.8 (33,312)	No diversion above station
16720300	Kaiwiki Stream near Kamuela	4,090 (1,247)	0.45 (1.16)	10	384 (1,453,598)	.02 (.76)	2.5 (9,464)	No diversion above station
16720500	Upper Hamakua Ditch below Kaiwiki Stream, near Kamuela	4,020 (1,225)	— —	14	32 (121,133)	.03 (.114)	5.2 (19,684)	Ditch diverts water from Kawaihui and Kawaiiki Streams
16724800	Upper Hamakua Ditch above Alakahi Stream, near Kamuela	3,890 (1,186)	— —	10	26 (98,421)	0 (0)	3.7 (14,006)	Ditch diverts water from Kawaihui and Kawaiiki Streams
16725000	Alakahi Stream near Kamuela	3,900 (1,189)	0.87 (2.25)	14	918 (3,475,008)	.02 (.76)	4.1 (15,520)	Parker Ranch diverts water from tributary above station
16726000	Upper Hamakua Ditch above Waimea Reservoir diversion, near Kamuela	3,020 (920)	— —	3	31 (117,348)	0 (0)	7.3 (27,634)	Ditch diverts water from Kawaihui, Kawaiiki and Alakahi Streams
16727000	Upper Hamakua Ditch above Puukapu Reservoir	2,890 (881)	— —	1	7 (26,498)	0 (0)	1.8 (6,814)	New station established 1977
16756000	Kohakohau Stream near Kamuela	3,273 (998)	2.51 (6.50)	22	2,508 (9,493,813)	0 (0)	5.4 (20,441)	Parker Ranch diverts above station at elevation 4,250 ft. (1,295 m)
								DOWAID diverts water at elevation 3,400 ft. (1,036 m)
16758000	Waikoloa Stream at Marine Farm, near Kamuela	3,460 (1,055)	1.18 (3.06)	31	2,191 (8,293,837)	.38 (1,438)	5.5 (20,820)	Diversion above station for domestic and livestock use
16759000	Hauani Gulch (Stream) near Kamuela	3,117 (950)	0.47 (1.22)	22	381 (1,442,242)	0 (0)	.94 (3,558)	Diversion above station for domestic and livestock use

Source: U.S. Geological Survey, Water Resource Data for Hawaii and Other Pacific Areas, Water Year 1978.



Legend:

- 7315 Active Gaging Station
▲ and Number
- 7415 Inactive Gaging Station
△ and Number
- 7515 Active Crest-Stage
▲ Station and Number

Stream Gaging
Stations

Figure 7

Ground Water

Basically, ground water in the study area occurs in three modes: basal, perched, and dike impounded (Fig. 8). Development of any of these modes would greatly enhance and supplement the surface water resource.

A vast reservoir of fresh basal water rests upon the much denser salt water at approximately sea level. Basal water is replenished by percolating rainfall and overflow from dike compartments and perched water bodies. It is usually brackish at the coastline, but the quality improves further inland.

Development of basal water probably began as early as the 1890's with wells being drilled for mill use (USGS Well Nos. 4, 5, and 6; Fig. 9 and Table 2) at Paauiilo and Kukaiau, which since then have been abandoned. Presently, there are two "Maui" or skimming shafts at Paauiilo and Ookala (USGS Shaft Nos. 5 and 6; Fig. 9 and Table 3) that are being used for domestic purposes. Together these shafts develop 3 to 4 MGD (11,300 to 15,100 m^3/D) of basal water along the Hamakua Coast. Further, DLNR has initiated drilling and is pump testing other wells in Haina and Laupahoehoe to develop supplemental domestic water sources.

Inasmuch as basal water is primarily at sea level, development of it for agricultural purposes in the higher elevations is precluded by the high pumping and well construction costs.

Perched water, trapped on layers of (1) intercalated beds of ash or soil and (2) dense lava with low permeability, appears as springs and tunnels (Fig. 9). An inventory of springs and tunnels (Tables 4 and 5) indicate that due to the low flows, undependability, and lower elevations very few springs or tunnels could be developed economically. Certain high level springs fed by dike compartments at the head of the canyons of Waipio Valley (USGS Spring Nos. 20-27; Table 5) are presently being diverted by the Lower Hamakua Ditch with overflow going into Waipio Stream.

Dikes in the Kohala Mountains that intersect the canyon walls of the Waipio Valley impound a substantial amount of water and are evidenced by spring discharges in the valley walls that have been exposed by erosion.

In their book, "Geology and Ground Water Resources of the Island of Hawaii," Stearns and Macdonald estimated an average low flow from dike compartments to be about 58 MGD (219,600 m^3/D).^{2/} Waipio Valley dikes inventoried by Stearns included the following:

<u>Valley</u>	<u>No. of Dikes^{3/}</u>
Hiilawe	4
Waima	36
Koiawe	78
Alakahi	62
Kawainui	16

^{2/} Stearns, H. T., and G. A. Macdonald, Geology and Ground Water Resources of the Island of Hawaii, 1946, p. 239.

^{3/} Ibid., p. 175

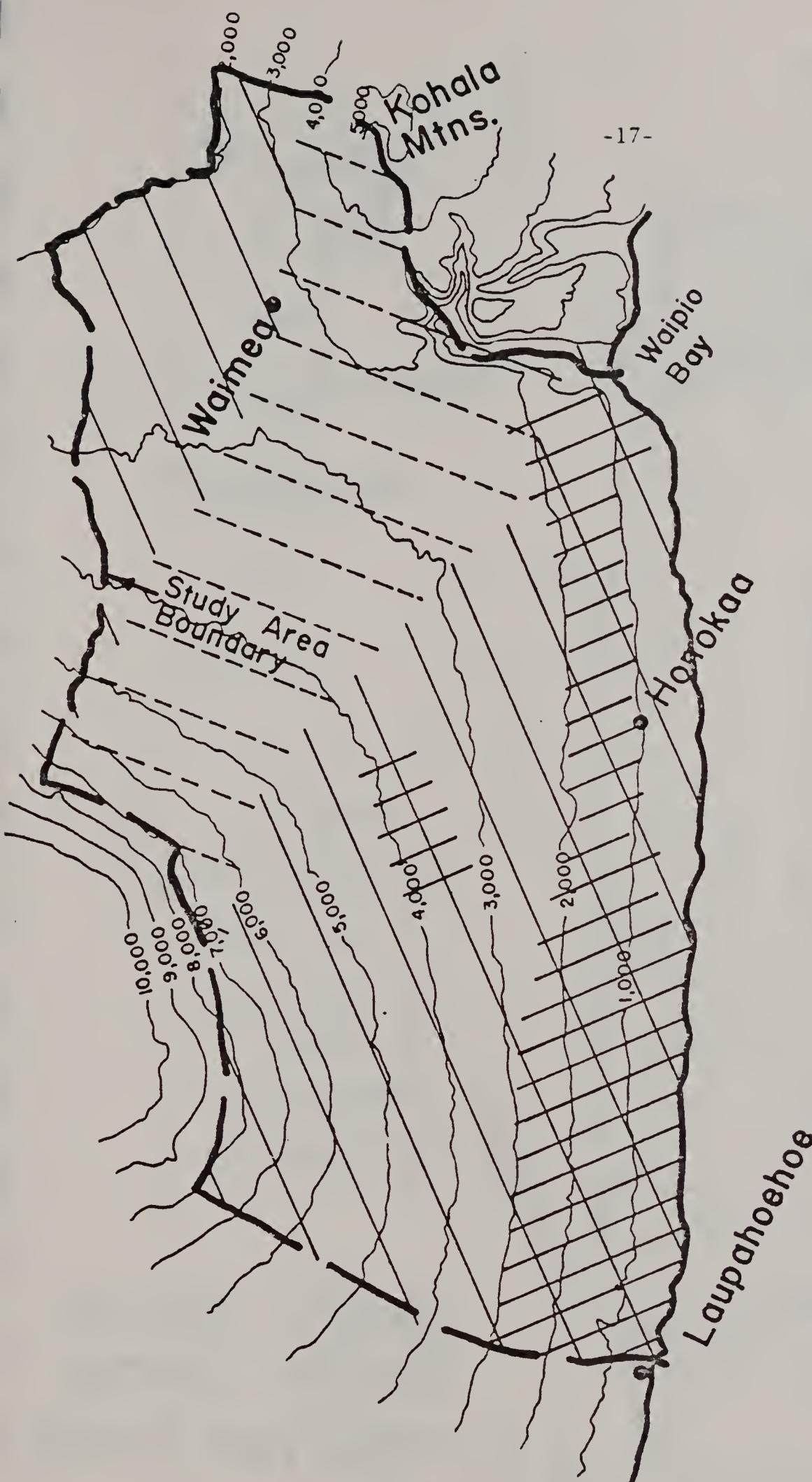
The Lower Hamakua Ditch intercepts spring discharges from the ditches at intakes in the Kawainui [1,037 feet (316 m) elevation], Alakahi [1,030 feet (314 m) elevation] and Koiawe [1,000 feet (300 m) elevation] Streams along with any overflow from the Upper Hamakua Ditch. During low flows, pumps at Waima River intake lift water up to the Lower Hamakua Ditch at a rate of 6 MGD (22,700 m³/D). Analysis of flow duration curve for the Lower Hamakua Ditch at the main weir of Kukuihale (Appendix B-7) indicates that during even low flows, spring discharge from dikes in the Kawainui, Alakahi, and Koiawe Valleys upstream of the intakes is about 17 MGD (64,400 m³/D) [excluding 6 MGD (22,700 m³/D) pumped from Waima Stream].

Spring discharge from dike compartments below the Lower Hamakua Ditch was estimated to be about 31.5 MGD (119,240 m³/D)^{4/} during low flows. Historically, this has been sufficient to supply the farmers of Waipio Valley.

Although development of dike impounded water from the Waipio side would be economically unfeasible and difficult due to the elevation difference and the steep valley walls, there is a possibility of exploitation of this high-level source from the southern flanks of the Kohala Mountains above Waimea by either deep or skimming wells (Maui type). However, drilling attempts to date by the U.S. Navy well (USGS well No. 3; Fig. 9 and Table 2 and DLNR test hole (USGS test hole No. 19, Fig. 9 and Table 6) both turned up dry down to elevation 2,965 feet (904 m) and 2,689 feet (810 m), respectively.

Additional exploratory wells and pumping tests should be done in order to locate and quantify what seems to be an abundance of dike impounded water in the Kohala Mountains. Proposed exploratory well sites as shown on Figure 6 should be drilled to at least elevation 1,500 feet (460 m).

^{4/} Ibid., p. 230

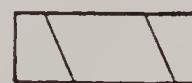


SCALE

5 0 5
MILES

5 0 5
KILOMETERS

LEGEND



Ground water perched in lava flows by ash beds, soil layers, or dense lava flows. Vertical-line symbol is superimposed on diagonal-line symbol where water is perched above dike-impounded ground water and on horizontal-line symbol where it is perched above basal water table



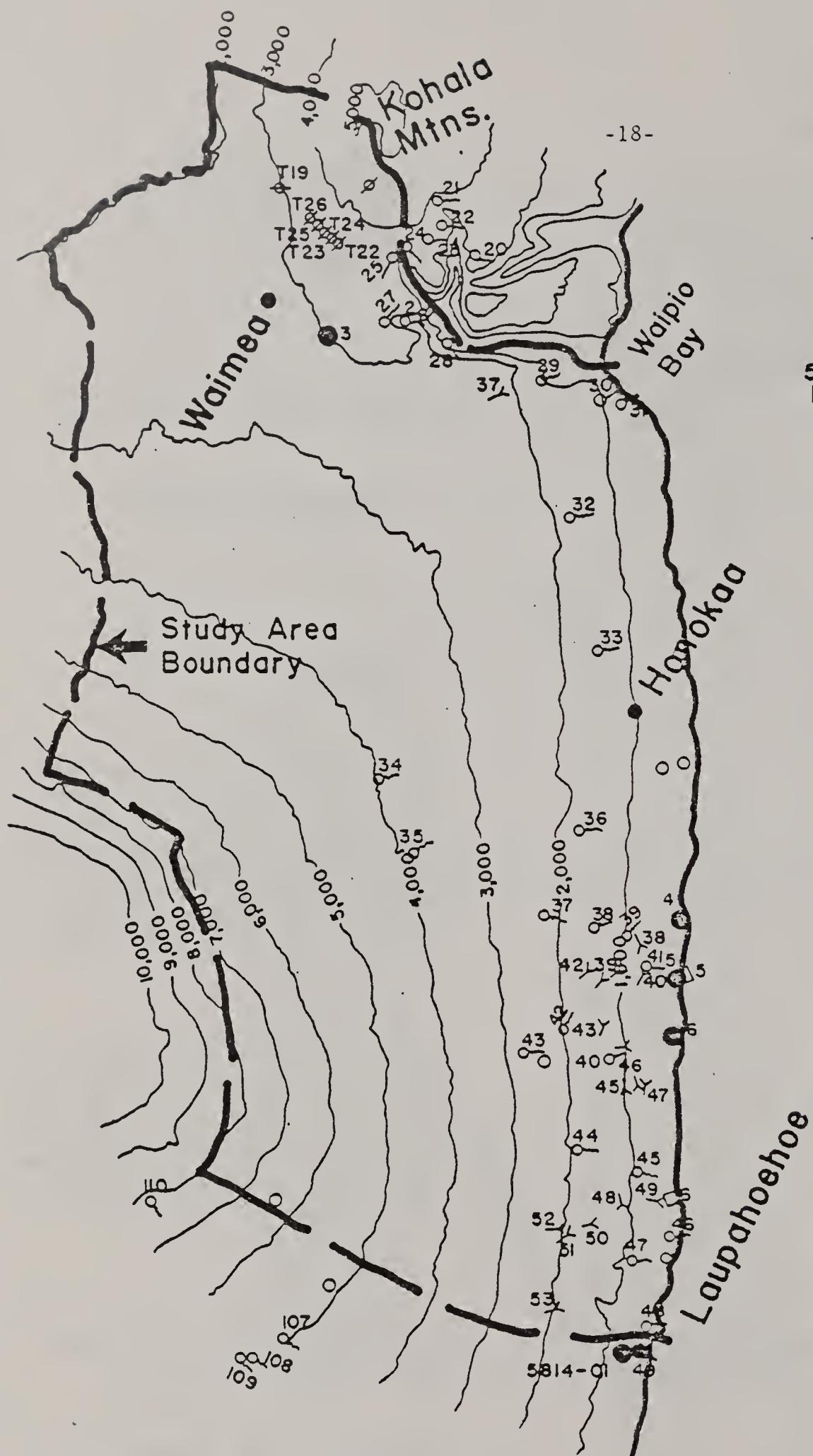
Ground water impounded in lava flows by dikes. Solid diagonal lines indicate generalized area in Kohala Mtns. where dikes and springs fed by dike-impounded are known to exist. Dashed diagonal lines indicate areas where water is presumed to be impounded by dikes.



Basal ground water in lava flows near sea level

Ground Water Map

Figure 8



SCALE

MILES

5 0 50
KILOMETERS

KILOMETERS

LEGEND:

- 9-10 Drilled Wells
- Dug Wells
- T8 Test Holes
- 9 Shafts
- >99 Tunnels
- 33 Springs

Wells, Tunnels, Shafts, Springs, And Test Holes

Figure 9

Source: An Inventory of Basic Water Resources Data:
Island of Hawaii Report R34
State of Hawaii, DLNR

TABLE 2
DRILLED WELL INDEX

USGS No.	DLNR No.	Well	Owner	N. Latitude	Elev. ft. (m)	Year Drilled (m)	Depth ft. (m)	Diam. in. (cm)	Water Level ft. (m)	Chloride Content ppm	Water Temp. of (°C)	Static Water Use	Data Location	Remarks
												Unused	USGS	Abandoned 1958
3	6239-01	Waimea	US Government	20°02'05" 155°39'42"	2855 (870)	1944 (271)	890 (20.3)	8 Dry						
4	6322-01	Paaui lo Davies		20 03 55 155 22 52	175 (53)	1894		12 (30.5)				"	"	Potable; ex livestock
5	6321-01	Paaui lo Mill	"	20 03 17 155 21 41	215.6 (65.7)	1894	217.1 (66.2)	12 (30.5)	1.7 (.5)	179	"	"	"	Ex domestic & industrial
6	6220-01	Kukaiau	"	20 02 43 155 20 27	244.7 (74.6)		264.7 (80.7)	12 (30.5)	2.2 (.7)	213	"	"	"	
5814-01		Laupahoehoe		19 58 57 155 14 23	659 (200.9)	1969	600 (182.9)	10 (25.4)	5.9 (1.8)	136	68 (20)			Domestic

TABLE 3
SHAFT INDEX

USGS No.	DLNR No.	Shaft	Owner	N. Latitude	Elev. ft. (m)	Year Constr.	Length ft. (m)	Inclined degree	Infiltr. Tunnels	No. of Static ft. (m)	Water Chloride Level Content ppm	Use
5	6321-02	Paaui Ilo	Davies	20° 03' 22"	273 (83)	1944	626 (191)	26	2	3.4 (1.0)	25-71	Irrigation; domestic; industrial
6	6117-01	Ookala	Davies	20 01 05	300 (91)	1937	650 (198)	30	2	6.0 (1.8)	7-15	Domestic; irrigation

Source: DLNR, An Inventory of Basic Water Resource Data: Island of Hawaii, Report R34, p. 158.

TABLE 4
TUNNEL INDEX

USGS No.	DLNR No.	Tunnel	N. Latitude W. Longitude	Elev. ft. (m)	Length ft. (m)	Yield gpd (m ³ /D)	Use	Remarks
37	6536-01	Lalakea Gulch* (SE Branch)	20° 05' 00" 155° 36' 00"	2200 (670)	580 (175)	0 (0)		
38	6222-01	Manienie Gulch (W side)	20 03 00 155 22 45	700 (215)	100 (30)	1,500 (6)		
39	6222-02	Paauiilo Stream	20 02 10 155 22 35	1060 (320)	50 (15)	50 (.2)	Domestic	Goes dry in dry weather
40	6222-03	Paauiilo Stream (E Bank)	20 02 45 155 22 15	700 (210)	25 (10)	100 (.4)		
41	6122-01	Kanui Gulch (E Bank)	20 01 55 155 22 35	1350 (410)	100 (30)	200 (.8)	Domestic	
42	6122-02	Paauiilo Gulch (E Bank)	20 01 40 155 22 50	1540 (470)	225 (70)	0 (0)	"	
42A	6122-03	Paauiilo Gulch	"	1580 (480)	100 (30)	100 (.4)		
43	6121-01	Kawaiili Stream (E Branch)	20 01 35 155 21 30	1500 (457)	100 (30)	50 (.2)		Goes dry in dry weather
44	6121-02	Kainehe Stream (E Branch)	20 01 40 155 20 55	1200 (366)	190 (60)	50 (.2)	Domestic	"
45	6120-01	Puumaila Stream (NW Bank)	20 01 25 155 20 05	1075 (328)	35 (10)	100 (.4)	"	
45A	6120-02	Puumaila Stream (SW Bank)	"	1075 (328)	30 (10)	50 (.2)	"	
46	6120-03	Puumaila Stream (NW Bank)	20 01 35 155 20 00	850 (259)	40 (10)	50 (.2)		
47	6119-01	Puumaila Stream (SE Bank)	20 01 45 155 20 00	800 (244)	30 (10)	300 (1.1)		
48	6017-01	Kaula Gulch	20 00 05 155 17 35	1200 (366)	15 (5)	0 (0)	Unused	
48A	6017-02	Kaula Gulch (NW Bk 25' N 48)	"	1200 (366)	30 (10)	0 (0)	"	
48B	6017-03	Kaula Gulch (NW Bk 50' N 48A)	"	1200 (366)	80 (25)	0 (0)	"	
49	6017-04	Kaula Gulch (NW Bk on rd cut)	20 00 55 155 17 20	640 (195)	450 (135)	0 (0)	"	

*Owned by Kohala Sugar Co. (37) all others owned by Davies Hamakua (38-53)

TABLE 4
TUNNEL INDEX (cont'd)

USGS No.	DLNR No.	Tunnel	N. Latitude	Elev.	Length	Yield	Use	Remarks
			W. Longitude	ft. (m)	ft. (m)	gpd (m ³ /D)		
50	5917-01	Small gulch 0.45 mi SE Kaula Gulch	19° 59' 20" 155° 17' 35" (488)	1600 (488)	400 (120)	0 (0)	Unused	
51	5816-01	Br Kaawalii Gulch	19 58 40 155 17 40	2000 (610)	150 (45)	0 (0)	"	
51A	5816-02	Br Kaawalii Gulch (60' SE No 50)	"	2010 (613)	20 (5)	0 (0)	"	
52	5816-03	Kaawalii Gulch (NW Bank)	19 58 35 155 17 45	2000 (610)	90 (30)	0 (0)	"	
53	5716-01	Br Kapili Stream	19 57 50 155 16 10	2075 (632)	100 (30)	100 (.4)		

Source: DLNR, An Inventory of Basic Water Resource Data: Island of Hawaii,
Report R34, pp. 166-167.

TABLE 5
SPRING INDEX

USGS No.	Spring	Owner	N. Latitude W. Longitude	Elev. (ft. (m))	Estimated Yield gpd (m ³ /D)	Use	Remarks
20	N branch of Kawainui Stream	State of Hawaii	20° 05' 50' 3000 155° 39' 15' (914)	5,000,000 (18,900)			
21	Plunge pool, Ulu Falls, Kawainui Stream	Bishop Museum	20 05 35 2250 155 40 30 (686)	6,000,000 (22,700)		Irrigation	
22	Northern Upper Kawainui Stream	"	20 05 25 3550 155 40 10(1082)	500,000 (1,900)		"	
23	Southern Upper Kawainui Stream	"	20 05 10 3550 155 39 55(1082)	500,000 (1,900)		"	
24	Plunge pool head of Alakahi Canyon	"	20 04 25 1475 155 40 10 (450)	1,000,000 (3,800)			
25	Spring in S bank, 50' above Alakahi Stream	"	20 04 20 1425 155 40 05 (454)	3,000,000 (11,400)			
26	Pool 25' above Koiawe Stream in W wall	"	20 03 50 1200 155 38 25 (366)	200,000 (750)			
27	In falls at head Koiawe Canyon	"	20 03 30 1650 155 38 40 (503)	2,000,000 (7,600)			
28	E wall at Waimea Canyon just below intake of ditch	"	20 04 10 850 155 37 30 (259)	1,000,000 (3,800)			
29	Pool at foot of Hiilawe Falls	"	20 06 10 300 155 35 50 (91)	8,000,000 (30,300)			
30	Kukuihaele	Davies Hamakua	20 07 10 900 155 34 50 (274)	250,000 (950)		Domestic	
31	Waiuliu	County Hawaii BWS	20 07 30 600 155 34 40 (183)	250,000 (950)		"	
32	Kapulena Stream	State of Hawaii	20 05 25 1650 155 32 40 (503)	250 (1)			
33	Ahualoa Stream	Honokaa Sugar Co	19 59 15 1450 155 29 30 (442)	1,000 (4)		Domestic	
34	Waikomakapo Spring	Richard Smart	19 59 15 4275 155 29 00(1303)	1,000 (4)		Goes dry in dry weather	
35	Palikua Spring	State of Hawaii	19 59 15 3850 155 27 05(1173)	10,000 (40)		"	

TABLE 5
SPRING INDEX (cont'd)

USGS No.	Spring	Owner	N. Latitude W. Longitude	Elev. ft. (m)	Estimated Yield gpd (m ³ /D)	Use	Remarks
36	Kalopa Gulch	Davies Hamakua	20° 02' 45" 1800 155° 25' 55" (549)	500 (2)			
37	W fork of Manienie Gulch	State of Hawaii	20 01 15 2250 155 24 30 (686)	500 (2)	Abandoned		
38	Gulch W of Manienie Gulch	Davies Hamakua	20 02 05 1510 155 23 50 (460)	50 (.2)		"	
39	"	"	20 02 30 1050 155 22 05 (320)	50 (.2)		"	Goes dry in dry weather
40	Sea cliff 0.4 mi NW Manienie Gulch	"	20 03 55 15 155 22 45 (5)	5,000 (20)		"	"
41	Paauiilo Gulch	"	20 02 30 730 155 22 05 (222)	10,000 (40)	Domestic		
41A	"	"	" 700 (213)	100 (.4)	Abandoned		
41B	"	"	" 675 (206)	100 (.4)		"	
42	Branch of Kawaiili Stream	"	20 00 30 2025 155 21 50 (617)	100 (.4)		"	Goes dry in dry weather
43	Kalapahapuu Stream	"	19 59 30 3075 155 21 45 (937)	40,000 (150)		"	"
44	Keehia Stream	Laupahoehoe Sugar Co	19 59 45 2000 155 19 10 (610)	250 (1)		"	
45	Kupapaulua Stream	"	20 00 35 1100 155 18 10 (335)	1,000 (4)	Domestic		
46	Kaahaoha Stream	"	20 00 45 450 155 16 20 (137)	4,000 (20)		"	
47	Kaawalii Spring	"	19 59 45 380 155 16 20 (116)	150,000 (570)	Abandoned		
48	Sea cliff just W of Kilau Stream	State of Hawaii	19 59 35 330 155 14 40 (100)	20,000 (80)			
49	Laupahoehoe Spring	Laupahoehoe Sugar Co	19 59 20 320 155 14 20 (98)	50,000 (190)	Domestic	Several springs close together	

TABLE 5
SPRING INDEX (cont'd)

USGS No.	Spring	Owner	N. Latitude W. Longitude	Elev. ft. (m)	Estimated Yield gpd (m ³ /D)	Use	Remarks
107	Waiokaumalo Stream at Spring Water Camp	Pepeekeo Sugar Co	19° 52' 15" 5100 155° 18' 00" (1555)	1000 (1555)	15,000 (60)		
108	Nauhi Spring	"	19 51 30 5150 155 17 50(1570)	5000 (1570)	15,000 (60)		
109	Nauhi Stream S Branch	"	19 51 20 5250 155 18 00(1600)	5000 (1600)	200,000 (760)		
110	Kanakaleonui Spring	Richard Smart	19 51 20 8000 155 22 15(2438)	8000 (2438)	5,000 (20)		Goes dry in dry weather

Source: DLNR, An Inventory of Basic Water Resource Data: Island of Hawaii,
Report R34, pp. 175-177.

TABLE 6
DRILLED TESTHOLE INDEX

USGS No.	DLNR No.	Testhole	Owner	N. Latitude W. Longitude	Elev. ft. (m)	Year Drilled	Depth ft. (m)	Diam. in. (cm)	Water Level ft.	Static Water Level ft.	Data Location
19	6341-01	Waiaka Gulch, Waimea	Hawaii State DOWALD Hole A	20° 03' 08" 155° 41' 53"(1101)	3613	1964	924 (280)	5-3	Dry	• DOWALD	
22	6340-01	Kohakohau, Waimea	Hawaii State DOWALD D H 1	20 03 30 155 40 48 (1192)	3910	1964	100 (30)	3	"	"	
23	6340-02	Kohakohau, Waimea	Hawaii State DOWALD D H 2	20 03 29 155 40 53 (1173)	3850	1964	100 (30)	3	"	"	
24	6340-03	Kohakohau, Waimea	Hawaii State DOWALD D H 3	20 03 28 155 40 57 (1149)	3770	1964	100 (30)	3	"	"	
25	6340-04	Kohakohau, Waimea	Hawaii State DOWALD D H 4	20 03 28 155 41 01 (1155)	3790	1964	100 (30)	3	"	"	
26	6340-05	Kohakohau, Waimea	Hawaii State DOWALD D H 5	20 03 27 155 41 04 (1175)	3850	1964	100 (30)	3	"	"	

Source: DLNR, An Inventory of Basic Water Resource Data: Island of Hawaii, Report R34, p. 141.

EXISTING WATER DISTRIBUTION SYSTEMS

Water distribution systems that presently service the study area consist of agricultural water systems, both private or public, and a municipal water system.

Agricultural Water System

Upper Hamakua Ditch (UHD) and Lalamilo System

Both of these systems (Figs. 10 and 11) are presently administered and managed by DLNR for irrigating the Lalamilo Farm Lots. The UHD diverts water from the Alakahi, Kawaiki, Kawainui, Koiawe, and Waima Streams in the Kohala Mountains above the town of Waimea. Through a system of lined ditches, flumes, and tunnels, UHD conveys water to a 60 MG (227,100 m^3) storage reservoir at elevation 2,900 feet (880 m). Thence, the Lalamilo system transports the water via a pipe system to another 4.5 MG (17,000 m^3) reservoir to the Lalamilo Farm Lots. The average consumption is about .66 MGD (2,498 m^3/D).

The UHD, originally about 23 miles (37 km) long, was built in 1910 by the Hawaiian Irrigation Company to flume cut sugarcane from the fields to the Paauhau Plantation and also to supply water to the homesteaders along the route. However, through the years the portion beyond Puu Pulehu Reservoir has been abandoned and it now terminates at the 60 MG (227,100 m^3) reservoir. The UHD is presently about 7 miles (11 km) long with capacity ranging from 41 MGD (155,200 m^3/D) to 102 MGD (386,100 m^3/D) (Table 7). Inherent with its age is the deterioration of ditch sides, slopes, and wooden flumes and, associated with this, are substantial losses in the system (Table 7). Rehabilitation or replacement of this system will cut down these losses.

Lower Hamakua Ditch (LHD)

The LHD, approximately 21 miles (34 km) long, was built in 1910 by the Hawaiian Irrigation Company and conveys irrigation water from its farthest sources at Kawainui Stream [elevation 1,037 feet (316 m)] to Paauilo [elevation 890 feet (271 m)]. Skirting the lower edge of Waipio Valley's palis, the LHD intercepts runoff from the Kawainui, Alakahi, and Koiawe Streams. In addition, during low flows two 3-MGD pumps can lift water 500 feet (152 m) from Waima Stream to the LHD. The ditch emerges at Kukuihaele [elevation 977 feet (298 m)], then parallels the Hamakua coastline and delivers water to the canefields below the ditch from Kukuihaele to Paauilo. The average flow at the main weir of Kukuihaele is 24 MGD (90,850 m^3/D) and other characteristics are shown in Table 7. Several reservoirs (Table 8) store water from the ditch for overnight storage.

The flow in the lower ditch is dependable and fairly constant. During major storms, much of the water in excess of the capacity of the system is wasted at Kukuihaele. Flow duration curve at the main weir at Kukuihaele (Appendix B-7) indicates a base flow from dike water above the stream intakes at about 17 MGD (64,400 m^3/D) if 6 MGD (22,700 m^3/D) is discounted for the pumpage at Waima Stream.

Parker Ranch

Within the study area, Parker Ranch maintains a stockwater pipe system (Makahalau and Waikii; Fig. 10). A rough average of .5 MGD (1,893 m³/D) is being diverted from the Kohakohau, Waikoloa, Alakahi, and Hauani Streams in the Kohala Mountains. The system is badly deteriorated and future plans call for its replacement.

Municipal Water System

The municipal water system (domestic, industrial and commercial) is administered by the Department of Water Supply (DWS), County of Hawaii (Fig. 10). Davies-Hamakua still does supply a limited number of customers with municipal water in the communities of Paauhau, Haina, Paauilo, and Ookala. Most of the water in the DWS system is derived from surface runoff and the rest from springs and wells that tap the basal aquifer.

Waimea-Puukapu, Kawaiahae, and Hamakua System

These systems serve the communities of Waimea, Puukapu, Ahualoa, and Honokaa. Water is diverted from the Waikoloa and Kohakohau Streams in the Kohala Mountains and stored in a series of reservoirs [2 - 50 MG (189,300 m³), 8.5 MG (32,200 m³), and 4 MG (15,100 m³)] on the slopes of Puu Ki above Waimea Town (Table 8). These reservoirs, along with a treatment plan, supply municipal water to the communities mentioned at a consumption rate of 2 MGD (7,600 m³/D).

Kukuihale System

Water from low level springs at elevation 5,400 feet (1,600 m) is pumped to a reservoir that supplies approximately 30,000 gallons per day (GPD) (114 m³/D) to the communities of Kukuihale and Kapulena.

Paauilo System

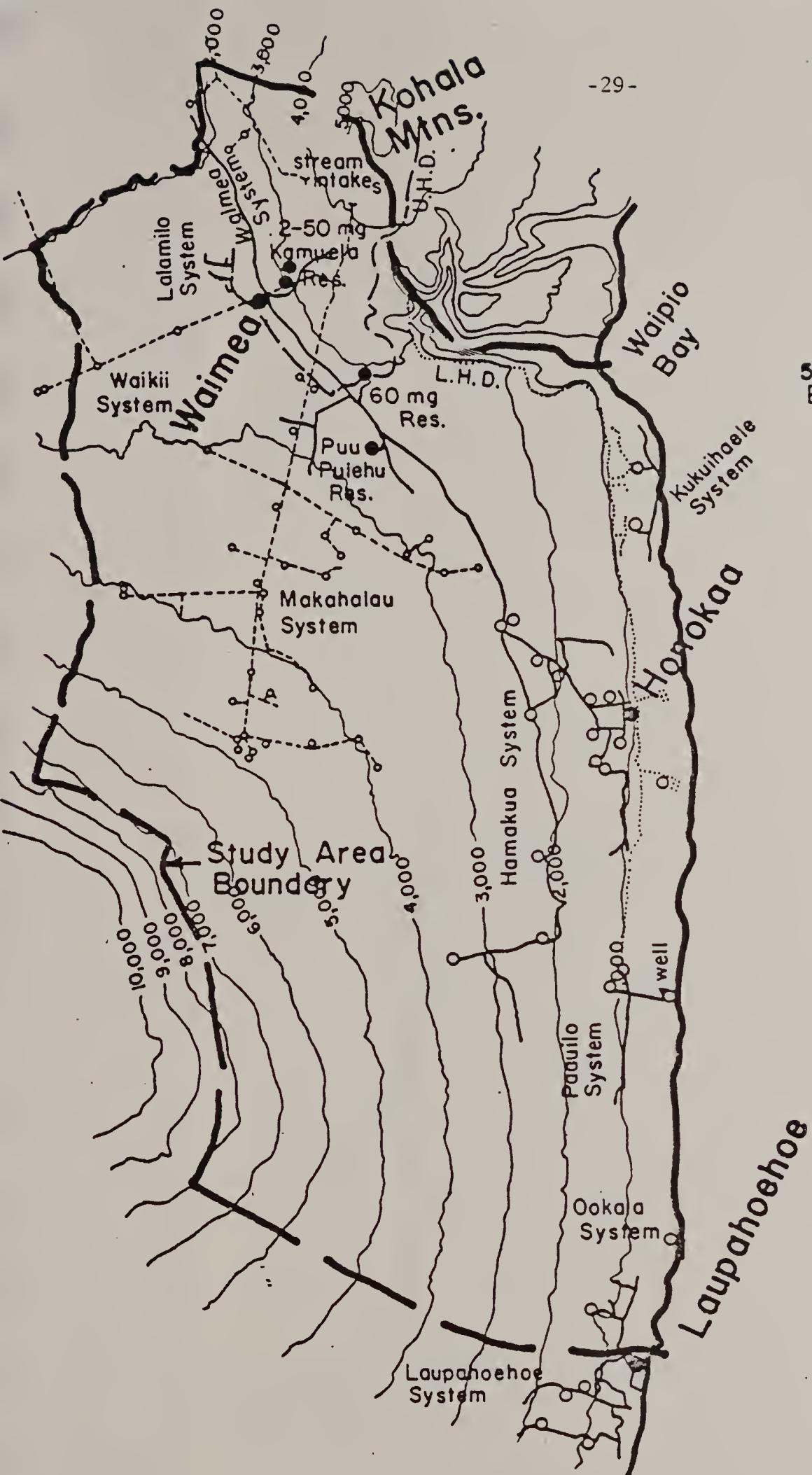
Presently, this system obtains water from Davies-Hamakua's deep well (USGS well No. 5; Fig. 9 and Table 2) below Paauilo Village; however, plans call for this system to be connected to the Hamakua System. Present consumption is approximately 25,000 GPD (100 m³/D).

Ookala System

Water obtained from a shaft (USGS shaft No. 6; Fig. 9 and Table 3) at elevation 300 feet (90 m) supplies approximately 7,000 GPD (30 m³/D) to the community of Ookala.

Laupahoehoe System

High level water in the Manawaiopae and Kuwaikahi Streams and a deep well (DLNR well No. 5814-01; Fig. 9 and Table 2) at elevation 659 feet (201 m) supply water to the town of Laupahoehoe at an average consumption rate of 75,000 GPD (300 m³/D). DLNR is presently drilling another deep well in the same vicinity.



-29-

SCALE

MILES

A scale bar for distance, marked with '5' at both ends and '0' in the center. Below the bar, the word 'KILOMETERS' is printed in a bold, sans-serif font.

LEGEND

- County BWS System
(Domestic)
- State System
(Irrigation)
- Hawaiian Irrigation
Co. System (Irrigation
& Domestic)
- Parker Ranch System
(Stock)
- Water Tank

Existing Water Systems

Source: An Inventory of Basic Water Resources Data:
Island of Hawaii Report R34
State of Hawaii DLNR

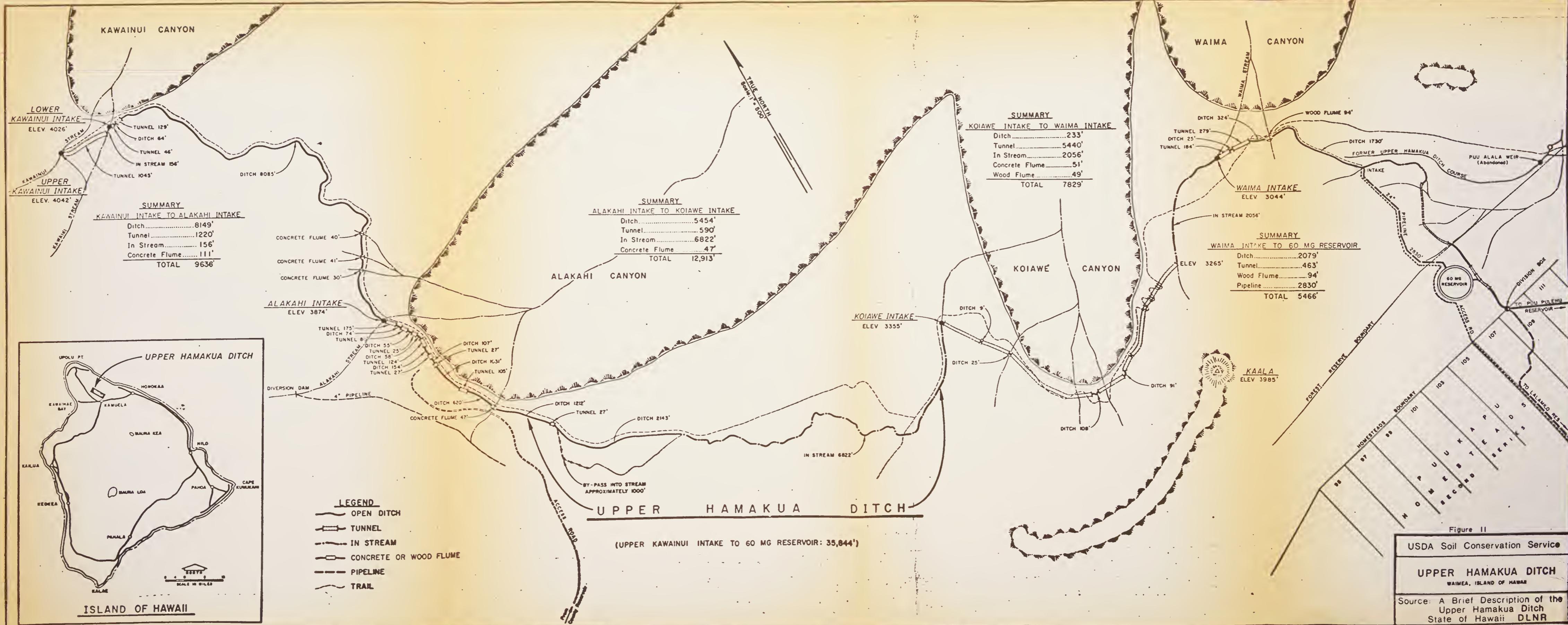


TABLE 7
UPPER AND LOWER HAMAKUA DITCH CHARACTERISTICS

System	Total Length feet (m)	Open Ditch feet (m)	Section-Length Tunnel Stream feet (m)	Wood or Concrete Flume feet (m)	Elevation Change feet (m)	Capacity MGD (m ³ /D)	Losses %
<u>Upper Hamakua Ditch</u>							
Kawaihui to Alakahi Intake	9636 <u>1</u> / (2937)	BW=3', TW=5', D=3.5' <u>2</u> / (0.9) (1.5) (1.1)	8149 (2484) <u>2</u> / (372)	1220 (48) BW=2.5', D=3 <u>2</u> / (0.8) (0.9)	111 (34) <u>3</u> / (1232-1181= 51)	4042-3874=168 (155, 200)	41 <u>2</u> / 37
Alakahi to Koiawe Intakes	12913 <u>1</u> / (3936)	5454 (1662)	590 (180)	6822 (2079)	47 (14)	3874-3355=519 (1181-1023=158)	54 <u>2</u> / to determine
Koiawe to Waima Intakes	7829 <u>1</u> / (2386)	233 (71)	5440 (1658)	2056 (627)	100 (30)	3355-3044=311 (1023- 928= 95)	652/ difficult
Waima Intake to 60mg Reservoir	5466 <u>1</u> / (1666)	2079 (634)	463 (141)	94 (29)	2830 (862)	3044-2924=120 (928- 891= 37)	246, 100 to determine
<u>Lower Hamakua Ditch</u>							
Kawaihui Intake to Main Weir	44741 <u>3</u> / (13637)	--	42286 (12889)	1750 (533)	705 (215)	1037-977=60 (316-298=18)	0
Kukuihaele Section	25319 <u>3</u> / (7717)	BW=7', TW=11' D=5' <u>6</u> / (2.1) (3.4) (1.5)	20315 (6192) (966)	--	BW=7', D=5' <u>6</u> / (2.1) (1.5)	977-966=11 (298-294= 4)	41 <u>4</u> / (155, 200)
Honokaa Section	23698 <u>3</u> / (7223)	BW=7', TW=11' D=5' <u>7</u> / (2.1) (3.4) (1.5)	17322 (5289) (1243)	4079 (12358 (3767)	BW=6.4' D=4' <u>7</u> / (2.0) (1.2)	966-920=46 (294-280=14)	25 <u>4</u> / (94, 600)
Paauhau Section	17467 <u>3</u> / (5324)	BW=8.6', TW=10.8' D=2.3' <u>7</u> / (2.6) (3.3) (0.7)	4008 (1222)	--	1101 (336)	920-903=17 (280-275= 5)	20 <u>4</u> / (75, 700)
Paauilo Section	2487 <u>3</u> / (758)	BW=1.0', TW=2.5' D=1.0' <u>7</u> / (0.3) (0.8) (0.3)	2232 (680) (38)	126 (38)	BW=1.0' D=1.2' <u>7</u> / (0.3) (0.4)	903-890=13 (275-271= 4)	5-10 <u>4</u> / (18, 900-37, 900)

1/ DOWARD
 2/ Waimea Plains Project, January 1948 - Bureau of Reclamation
 3/ Davies-Hamakua Sugar Co., Map of Upper and Lower Hamakua Ditch dated April 1 1922
 4/ From Davies-Hamakua and field checked 6/79
 5/ From Davies-Hamakua
 6/ Hawaiian Annual - 1911, Page 140
 7/ Field checked 6/79

BW = Bottom width
 TW = Top width
 D = Depth

TABLE 8
INVENTORY OF RESERVOIRS
HAWAII AREA AGRICULTURAL WATER STUDY

<u>Reservoir</u>	<u>Purpose</u>	<u>Storage MG (m³)</u>	<u>Surface Area acres (hectares)</u>	<u>Top Elevation feet (m)</u>	<u>Bottom Elevation feet (m)</u>
<u>Davies-Hamakua^{1/}</u>					
Lalakea	Irrigation	36	4.2		
Haina W23	Irrigation	(136,300)	3.5	(1.7)	
E13	Irrigation	(13,300)	17		
E23	Irrigation	(64,300)	3.5		
Paauiilo 324	Irrigation	(13,300)	10		
W116 (Planned)	Irrigation	(37,900)	20		
<u>DLNR^{2/}</u>					
60MG	Irrigation	60	4.7	2976	2924
Lalamilo	Irrigation	(227,100)	(1.9)	(907)	(891)
		4.5	.2		2631
		(17,000)	(0.1)		(802)
<u>Dept. of Water Supply^{3/}</u>					
Puupulehu	Pending	102	34	2840	
		(386,100)	(13.8)	(866)	
50MG - 1	Domestic Water	48.7	7.7	3332	3330
50MG - 2	Domestic Water	(184,300)	(3.1)	(1016)	(1015)
8.5MG	Domestic Water	48.8	6.7	3354	3327
4.0MG	Domestic Water	(184,700)	(2.7)	(1022)	(1014)
		8.5			
		(32,200)			
		4.0			
		(15,100)			

^{1/} Data from Davies-Hamakua.

^{2/} Data from DLNR.

^{3/} Data from Dept. of Water Supply.

WATER QUALITY

The major sources of agricultural water in the study area are primarily stream or surface runoff and some ground water from basal water systems. Inherent with the use of these sources is the occurrence of certain objectionable constituents in the water which include dissolved solids and toxic elements.

In general, surface and ground water sources are well suited for irrigation and livestock uses. Table 9 shows water quality values for selected stations (see Figs. 6 and 12) and recommended maximum values for livestock and irrigation water by the Environmental Protection Agency (EPA). It should be noted that these recommended values by EPA should be used as general guidelines. To accurately determine the tolerance levels, it is necessary to look closely at the crops and livestock being raised in relation to the soils and climate. The Department of Health, State of Hawaii, has not established any livestock water quality standards under Water Quality Standards (revised Chapter 37-A) and has specifically excluded irrigation water standards from this chapter. This revised Chapter 37-A is yet to be approved by EPA.

Suitability of water for irrigation purposes is determined by the amount and types of salts present and toxicity. Excessive salts or high total dissolved solids can contribute to salinity and permeability problems in the crops and soil and thus reduce productivity. Total dissolved solids, consisting mainly of chloride, bicarbonate and sodium, for surface and ground water stations are well below the recommended EPA maximum of 350 mg/l.

Excessive concentrations of toxic elements in irrigation water can affect crop yields and possibly cause crop failure. Toxic elements of most concern are sodium, chloride, boron, and trace metals, of which only boron hasn't been measured in the past. In evaluating water quality values in Table 11, concentrations of toxic elements in surface and ground water sources are within the EPA irrigation water maximums except for the occurrence of selenium in surface runoff.

Livestock and poultry are highly sensitive to the salinity of water. Excessive salinity (high total dissolved solids) in livestock water can cause physiological upset or even death in livestock. Also, high concentrations of trace metals in stockwater can cause toxicity problems that render meat or poultry unsafe for human consumption. Although solids such as sodium, calcium, magnesium, chloride, sulfate, and bicarbonate are largely responsible for salinity in water, they are individually not very toxic. Water quality values for surface and ground water sources in Table 11 are within salinity and toxicity stockwater limits set by EPA.

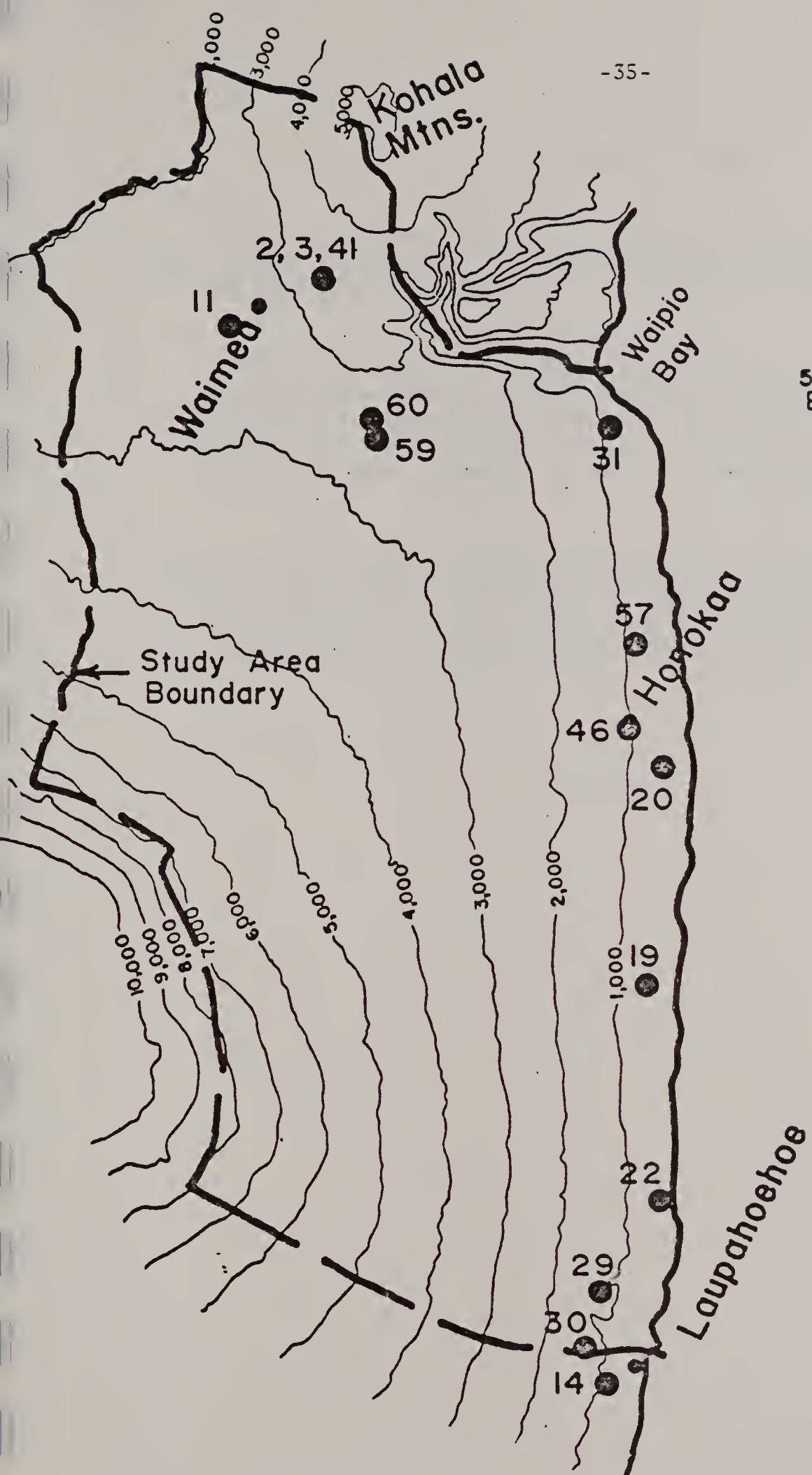
Additional water quality samples from selected streams and ditches will be collected and analyzed as part of the environmental impact assessment for this study.

TABLE 9
SURFACE AND GROUND WATER QUALITY VALUES - HAMAKUA AREA AGRICULTURAL WATER STUDY

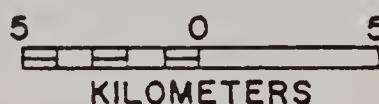
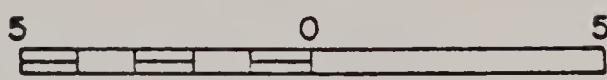
Irrigation and drainage paper #29, Food and Agricultural Organization:

2/ Agricultural Waste Management Field Manual, U.S. Department of Agriculture; and Irrigation and Drainage Paper #29, Food and Agricultural Organization.

Sources: Values for Water Quality from U.S. Geological Survey, Water Resources Data, 1975 and 1976; and Hawaii State Department of Land and Natural Resources, An Inventory of Basic Water Resources Data: Island of Hawaii, Report R34.



SCALE



Water Quality Sampling Sites

Source: An Inventory of Basic Water Resources Data:

Island of Hawaii Report R34
State of Hawaii, DLNR

Figure 12

SUMMARY OF FINDINGS

The most promising source of water is from the Kohala Mountains. Diversion of surface runoff from selected streams and possibly supplemental supply from high level dike seem economically feasible. Proposals as a result of this report include:

1. Divert water from the Kawainui, Kawaiki, Alakahia, and possibly the Kohakohau, Waikoloa and Hauani Streams. Monthly yield data for these streams, either individually or in combination, have been tabulated to be used in the reservoir operations or water budget analysis. In addition, flow duration curves have been presented to determine minimum stream discharge to be maintained.
2. Further exploratory test holes and pumping tests down to at least elevation 1,500 feet (457 m) as proposed in Figure 6 need to be performed to more definitely locate and quantify the high level dike water in the Kohala Mountains. Development of this source can only be feasibly done from the southwestern slopes of the Kohala Mountains by either deep wells or the skimming wells (Maui type).

APPENDICES

APPENDIX A

Monthly Yields

MONTHLY YIELDS
Appendix A-1

Station: 16720000

Period of Record: 1965-1978

Name: Kawainui Stream near Kamuela

Year	Monthly Yield (MG)											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1969	34	44	345	232	733	476	854	122	106	450	508	249
1970	51	130	236	231	60	319	824	492	305	486	580	172
1971	194	317	831	203	46	329	329	103	147	329	54	51
1972	125	310	292	125	183	187	531	72	136	310	371	113
1973	139	632	156	322	286	912	319	270	197	299	57	161
1974	208	394	102	318	75	151	417	158	103	116	227	21
1975	227	181	296	324	310	414	345	152	120	269	332	59
1976	362	215	74	303	247	404	440	164	266	440	245	107
1977	170	437	212	26	123	629	831	192	177	622	508	87
1978	258	173	271	208	30	472	259	218	398	697	440	192

MONTHLY YIELDS
Appendix A-2

Station: 16720300

Period of Record: 1969-1978

Name: Kawaiki Stream near Kamuela

Year	Monthly Yield (MG)											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1969	7	14	97	68	197	125	238	36	34	116	149	73
1970	18	31	63	62	16	86	210	137	85	145	164	47
1971	48	88	200	65	12	83	90	30	39	82	17	11
1972	29	74	69	30	43	42	136	24	36	83	101	32
1973	39	139	39	80	73	207	80	74	49	83	18	41
1974	55	87	31	73	20	37	101	48	32	41	70	11
1975	52	48	66	74	80	105	89	48	39	80	95	20
1976	97	58	25	78	60	116	118	65	88	128	73	41
1977	60	126	73	14	37	150	222	68	68	174	144	30
1978	69	44	52	74	11	106	59	57	109	194	147	76

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MONTHLY YIELDS
Appendix A-3

Station No.: 16725000
Name: Alakahi Stream near Kamuela
Period of Record: 1965-1978

Year	Monthly Yield (MG)											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1969	15	21	140	99	302	241	446	80	64	199	246	152
1970	33	45	94	91	22	139	319	230	145	246	290	102
1971	95	174	298	104	27	129	155	79	47	150	34	30
1972	58	124	130	50	71	64	205	44	55	146	157	74
1973	64	220	75	132	125	325	146	132	89	155	36	73
1974	96	137	64	125	47	64	180	105	70	99	188	35
1975	92	76	96	114	127	185	138	86	63	142	181	50
1976	143	104	50	124	109	202	205	114	142	231	136	62
1977	94	172	91	15	39	202	222	70	78	210	184	48
1978	125	79	98	132	28	165	83	101	184	352	243	134

MONTHLY YIELDS
Appendix A-4

Station No.: 16756000
Name: Kohakohau Stream near Kamuela
Period of Record: 1957-1978

Year	Monthly Yield (MG)											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1969	0	3	114	74	314	171	339	14	4	62	205	55
1970	3	5	69	72	0	43	333	200	72	231	256	22
1971	28	121	441	161	0	93	62	0	10	100	0	0
1972	1	50	103	16	39	95	202	2	19	116	163	14
1973	3	242	17	108	85	331	54	39	21	65	0	3
1974	77	139	40	191	23	25	243	92	22	35	124	22
1975	46	58	118	158	120	300	129	11	3	102	114	6
1976	134	106	21	151	125	277	277	80	144	309	92	18
1977	28	238	81	0	15	292	495	79	70	332	300	26
1978	72	28	81	186	1	196	63	78	180	450	261	84

MONTHLY YIELDS
Appendix A-5

Station No.: 16758000

Name: Waikoloa Stream at Marine Dam near Kamuela

Period of Record: 1948-1978

Note: Diversion by DWS
downstream of
gage considered

Year	Monthly Yield (MG)											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1969	0	0	49	1	110	62	153	0	1	10	58	0
1970	0	0	32	10	0	3	109	55	5	44	121	0
1971	0	32	108	38	0	63	2	0	0	32	0	0
1972	0	0	1	0	4	22	88	0	0	19	122	0
1973	0	12	0	32	39	162	16	7	0	2	0	0
1974	0	41	0	28	0	6	44	0	0	0	4	0
1975	16	3	3	19	30	20	11	0	0	1	2	0
1976	0	2	0	32	0	1	16	0	7	53	0	0
1977	0	53	53	0	0	5	208	0	1	20	59	0
1978	0	0	20	48	0	8	0	0	22	60	14	0

MONTHLY YIELDS
Appendix A-6

Station No.: 16759000

Name: Hauani Gulch (Stream) near Kamuela

Period of Record: 1957-1978

Year	Monthly Yield (MG)											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1969	5	3	46	14	63	58	141	20	16	38	54	24
1970	6	6	30	29	4	23	89	66	37	72	91	18
1971	13	31	70	46	6	40	28	4	10	37	4	2
1972	4	11	16	5	13	13	55	4	6	24	62	8
1973	6	52	11	34	35	101	32	23	12	28	4	4
1974	10	30	8	23	4	8	22	12	6	8	22	3
1975	16	8	9	16	30	37	24	9	4	19	29	5
1976	22	17	4	25	10	26	37	13	23	57	15	6
1977	7	53	22	4	3	50	131	14	15	58	72	8
1978	15	8	19	37	3	32	8	11	32	79	54	22

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COMBINED MONTHLY YIELD
Appendix A-7

Station: Upper three streams
Name: Kawainui, Kawaiki and Alakahi Streams
Period of Record: 1969-1978

Year	Monthly Yield (MG)											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1969	56	79	582	399	1232	842	1538	238	204	765	903	454
1970	102	206	393	384	98	544	1353	859	533	877	1034	321
1971	337	579	1329	372	85	541	574	212	235	561	105	92
1972	212	508	491	205	297	293	872	140	227	539	629	417
1973	242	991	270	534	484	1444	545	476	535	537	111	275
1974	359	618	197	516	142	252	698	311	205	256	485	67
1975	371	305	458	512	517	704	572	286	222	491	608	129
1976	602	377	149	505	416	722	763	343	496	799	454	210
1977	324	735	376	55	199	981	1375	330	325	1006	836	165
1978	452	296	421	414	69	743	401	376	691	1243	830	402

COMBINED MONTHLY YIELD
Appendix A-8

Station: All streams
Name: Kawainui, Kawaiki, Alakahi, Kohakohau, Waikoloa and Hauani Streams
Period of Record: 1969-1978

Year	Monthly Yield (MG)											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.
1969	61	85	791	488	1719	1133	2171	272	225	875	1220	533
1970	111	217	524	495	102	613	1884	1180	649	1224	1502	361
1971	378	763	1948	617	91	737	666	216	253	730	109	94
1972	217	569	611	226	353	423	1217	146	252	698	976	439
1973	251	1297	298	708	643	2038	647	555	368	632	115	282
1974	446	828	245	738	169	291	1007	415	233	299	635	92
1975	449	374	588	705	697	1061	736	306	229	613	753	140
1976	758	502	174	562	551	1026	1093	436	670	1218	561	234
1977	359	1079	532	59	217	1328	2209	423	409	1416	1267	199
1978	539	352	541	685	72	979	472	465	925	1832	1159	508

Appendix A-9

COMBINED MONTHLY YIELD FOR
VARIOUS PERCENT PROBABILITIES

STATION: Upper three streams
NAME: Kawaiinui, Kawaiki and Alakahi Streams
PERIOD OF RECORD: 1969-1978

MONTH	MONTHLY YIELD (MG)		
	90%	80%	50%
OCTOBER	110	154	271
NOVEMBER	159	228	412
DECEMBER	170	238	414
JANUARY	160	215	354
FEBRUARY	62	111	272
MARCH	327	423	655
APRIL	443	555	822
MAY	167	215	332
JUNE	178	223	330
JULY	366	453	658
AUGUST	188	276	521
SEPTEMBER	93	130	226

STATION: All streams
NAME: Kawaiinui, Kawaiki, Alakahi, Kahakohau, Waikoloa and Ilaunani Streams
PERIOD OF RECORD: 1969-1978

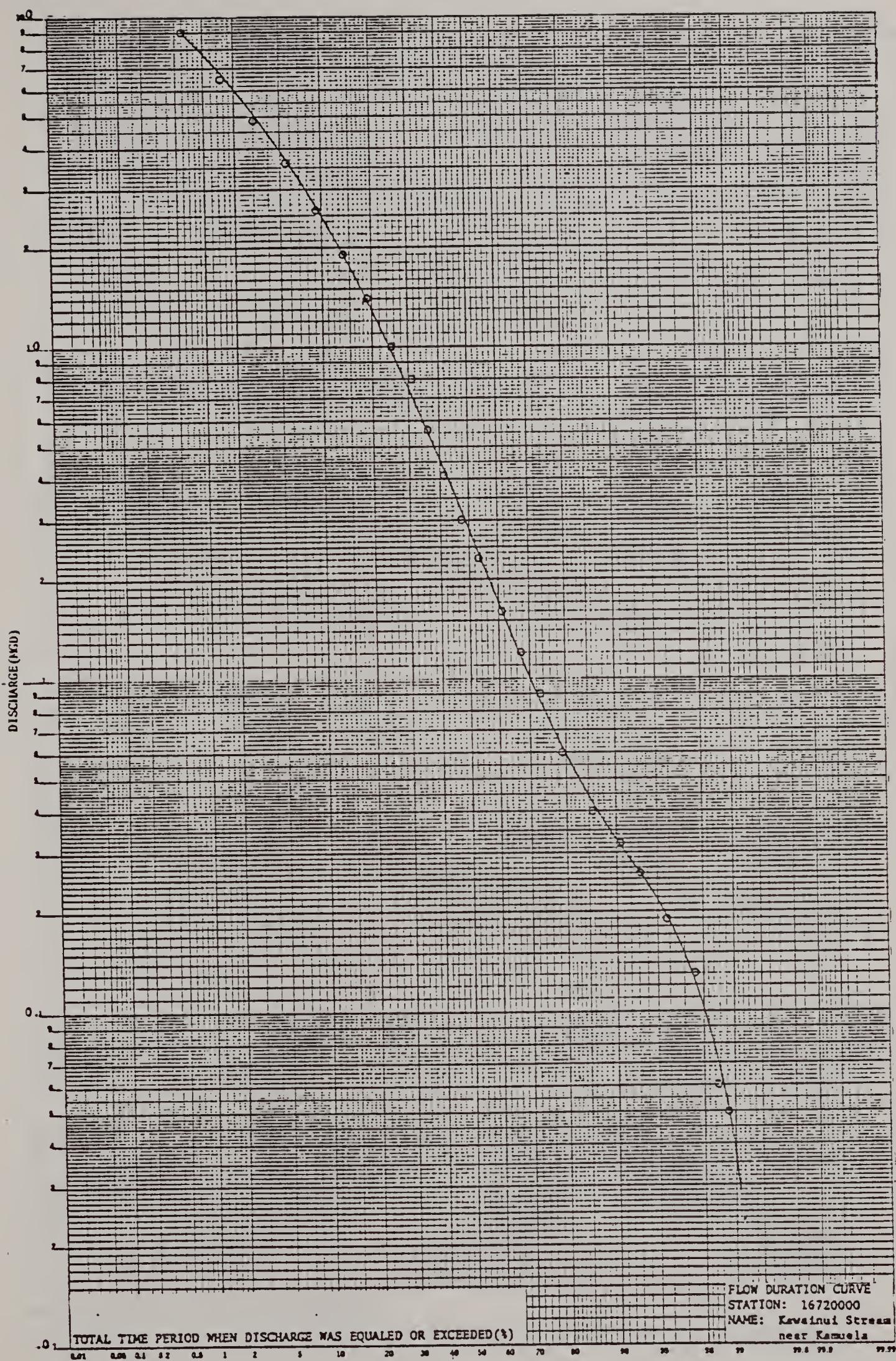
MONTH	MONTHLY YIELD (MG)		
	90%	80%	50%
OCTOBER	117	169	313
NOVEMBER	175	263	514
DECEMBER	202	294	547
JANUARY	197	275	479
FEBRUARY	66	127	344
MARCH	424	558	892
APRIL	530	698	1116
MAY	180	243	404
JUNE	186	245	392
JULY	444	571	884
AUGUST	210	331	690
SEPTEMBER	106	147	257

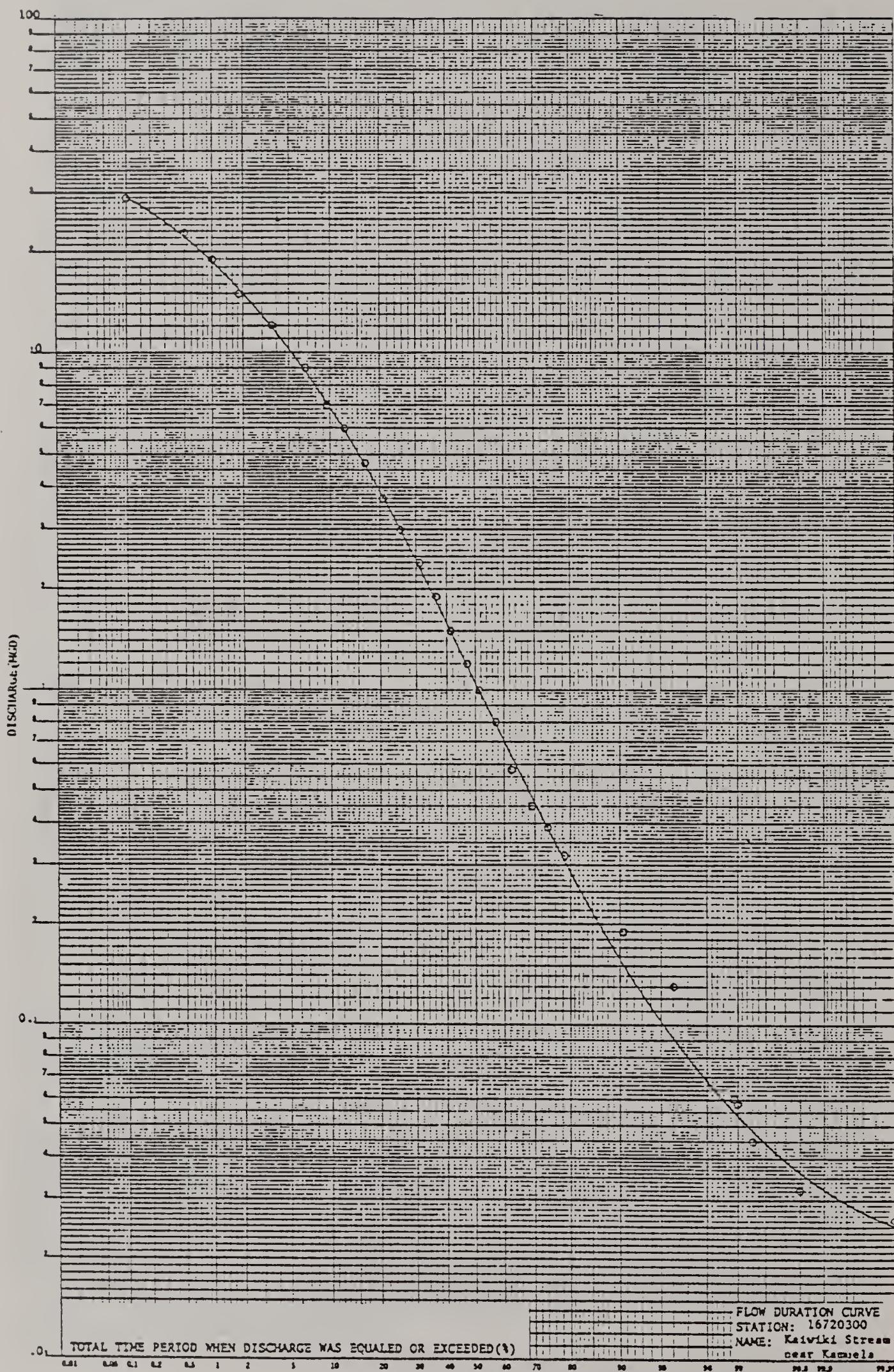
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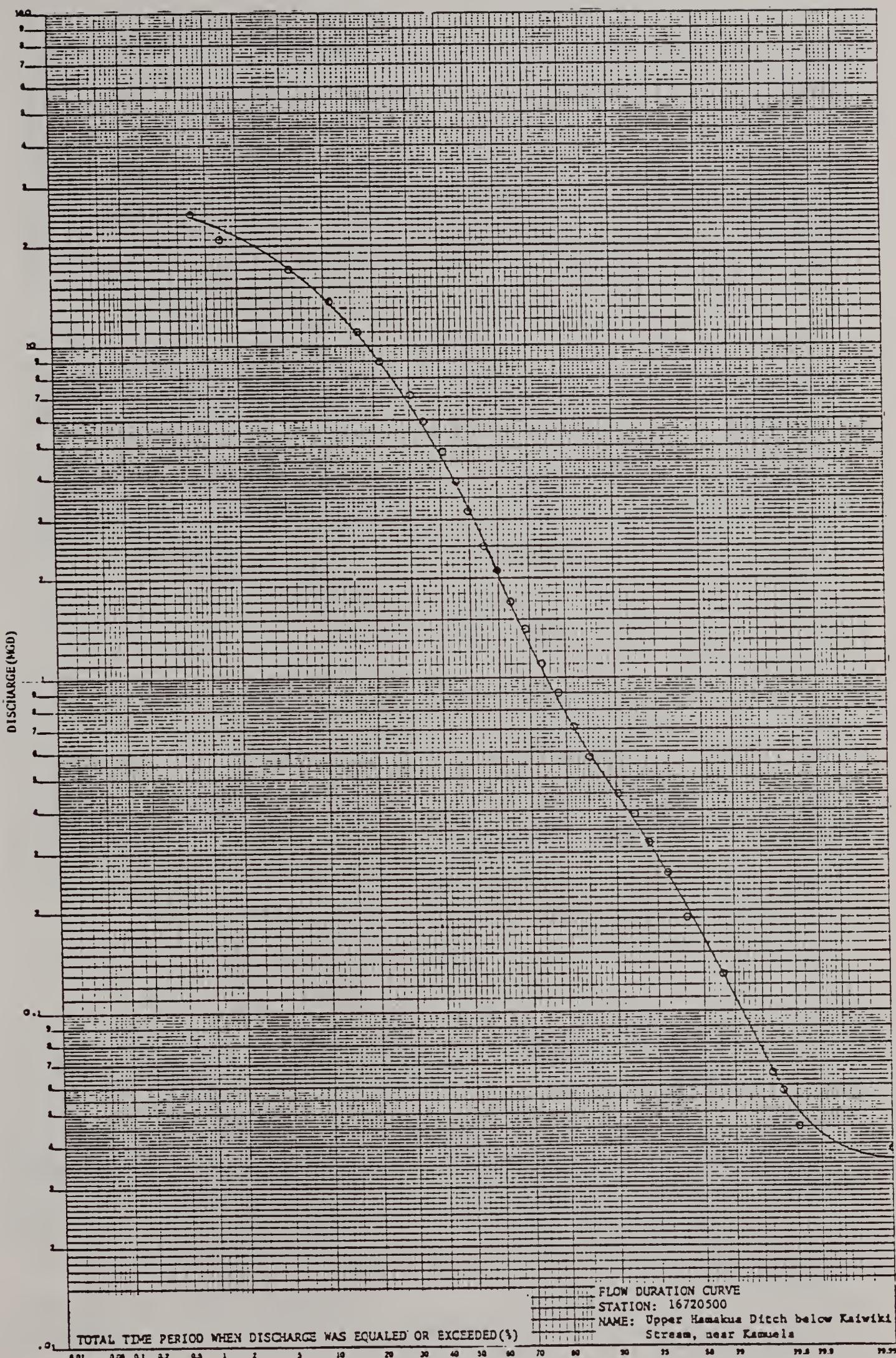
COMBINED MONTHLY YIELD FOR
VARIOUS PERCENT PROBABILITIES

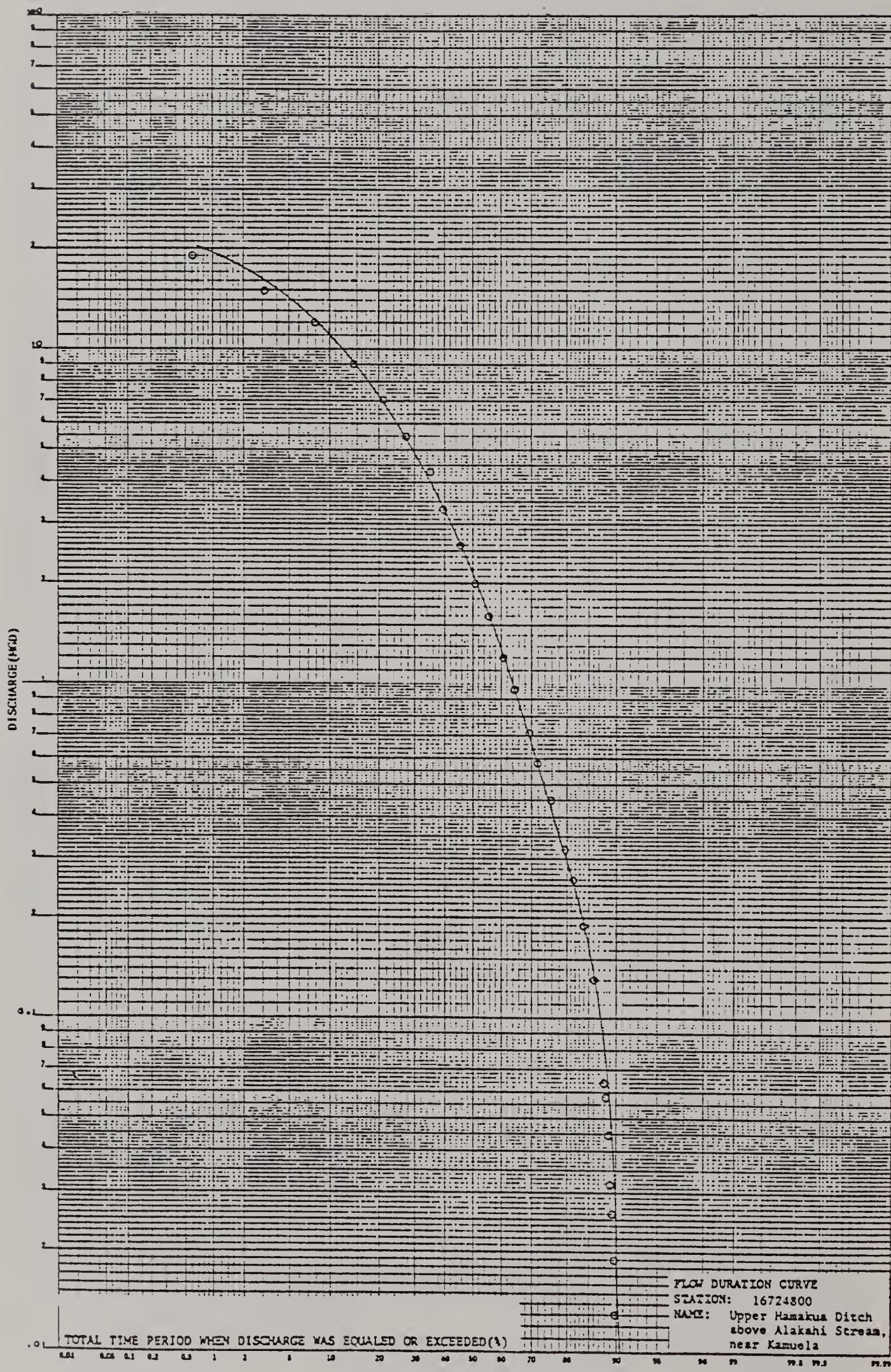
APPENDIX B

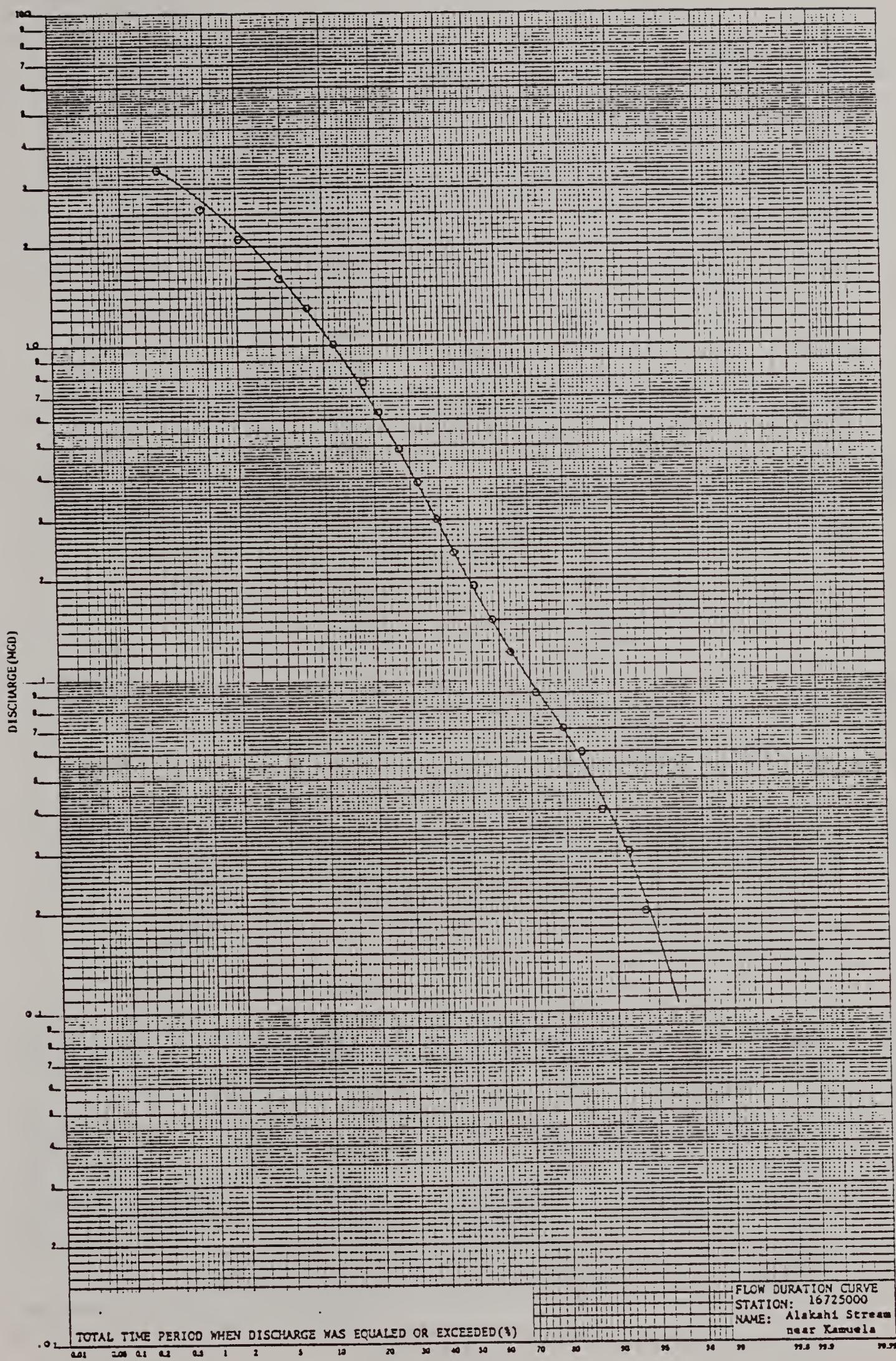
Flow Duration Curves

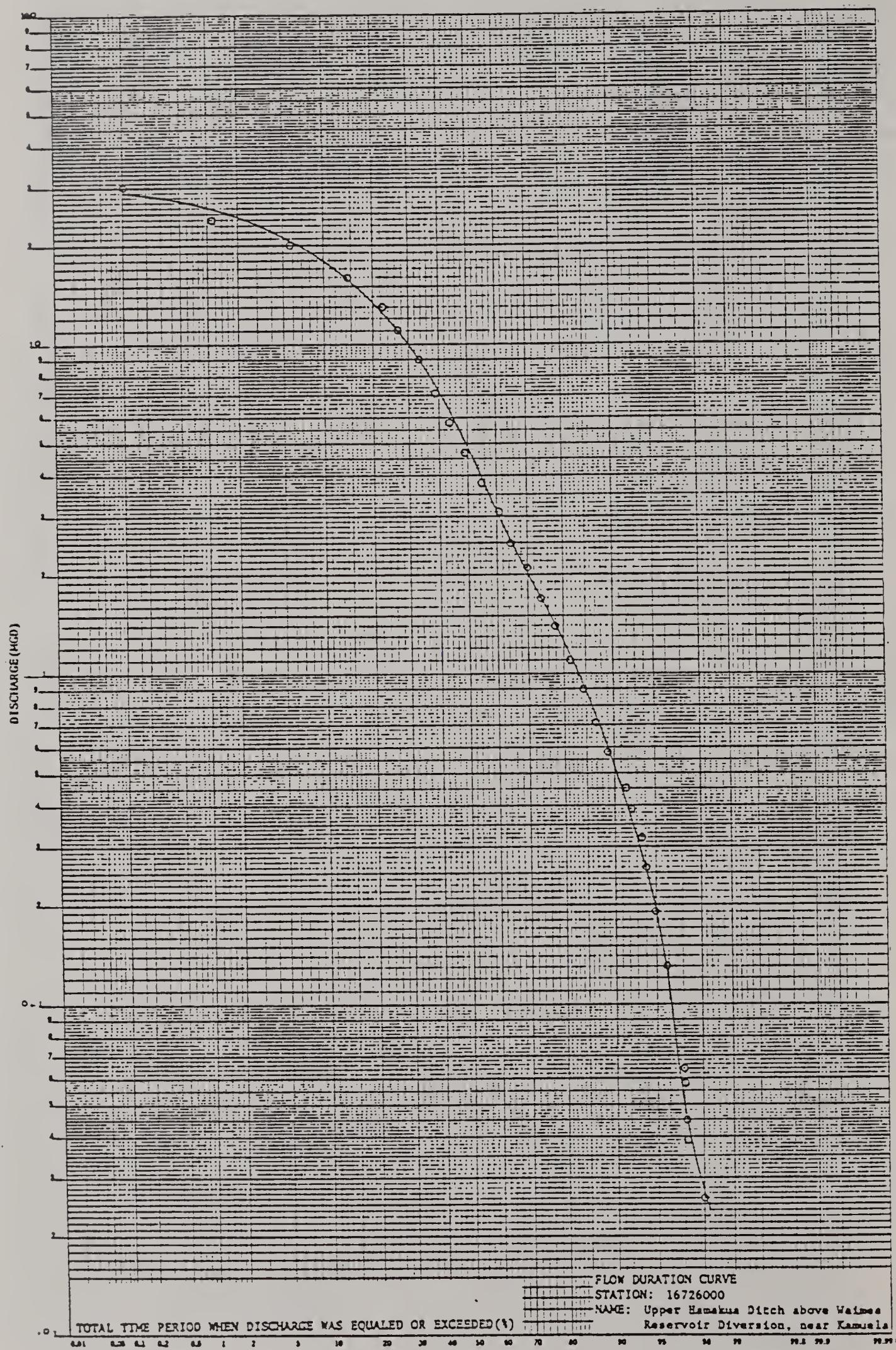


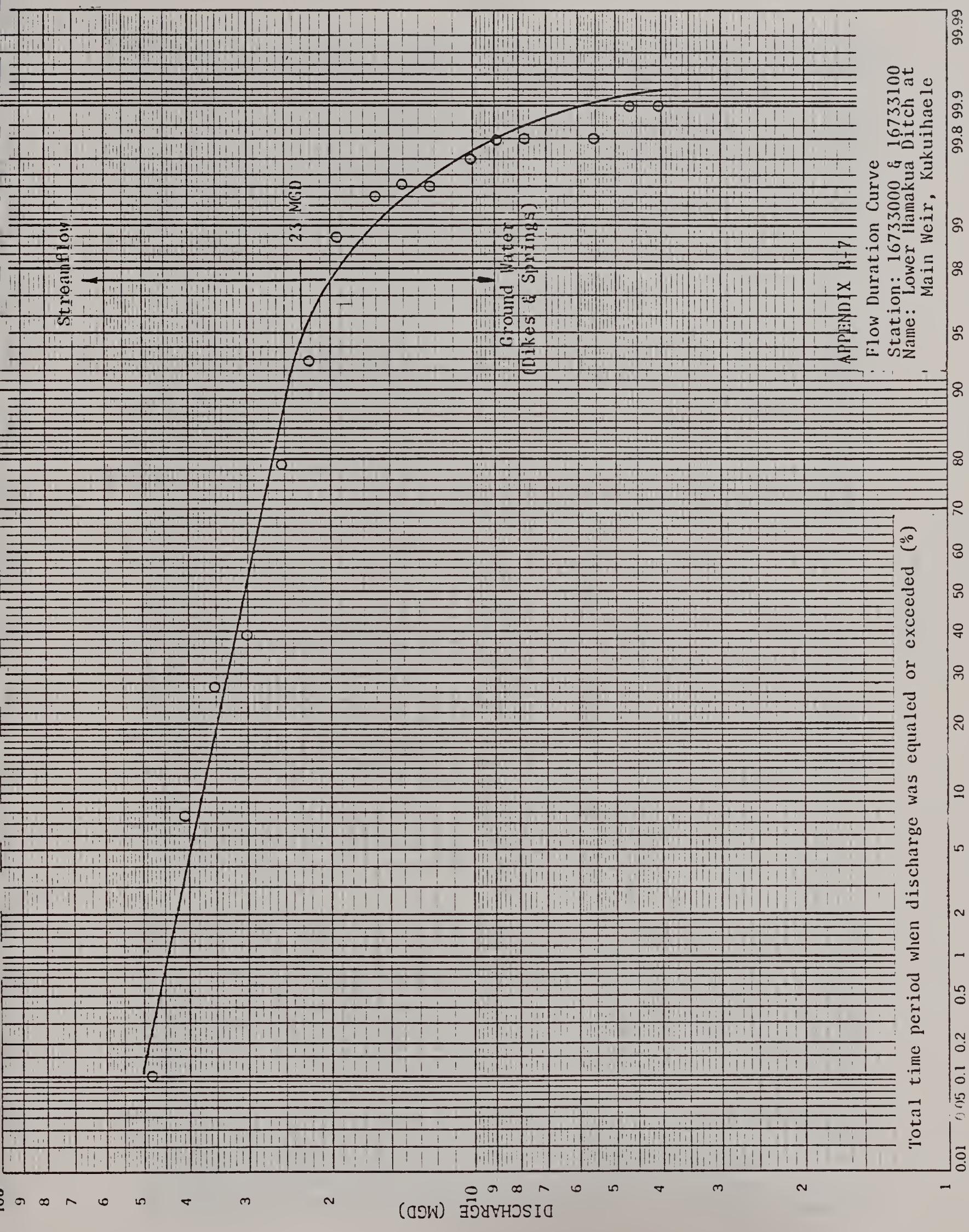


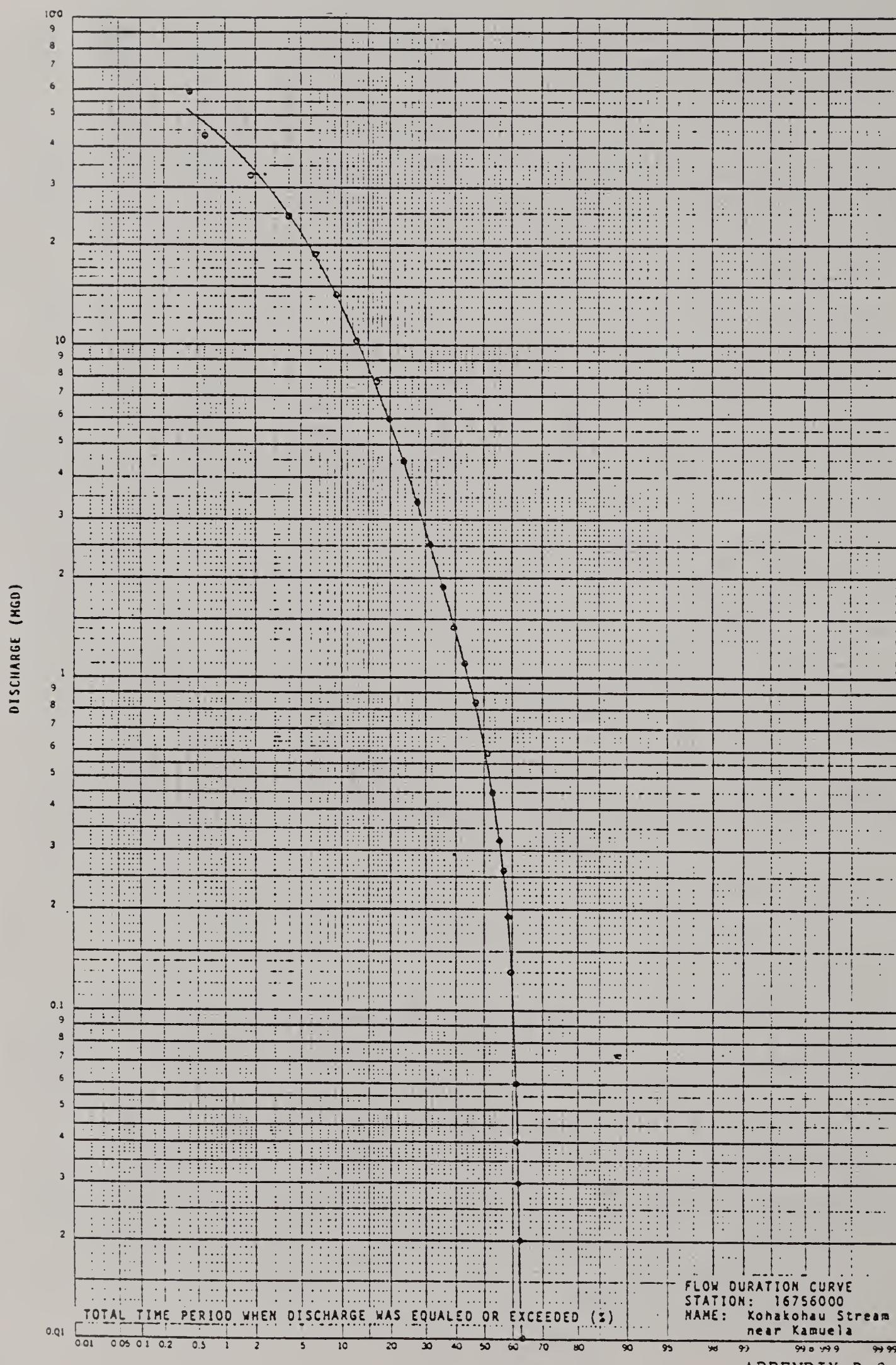


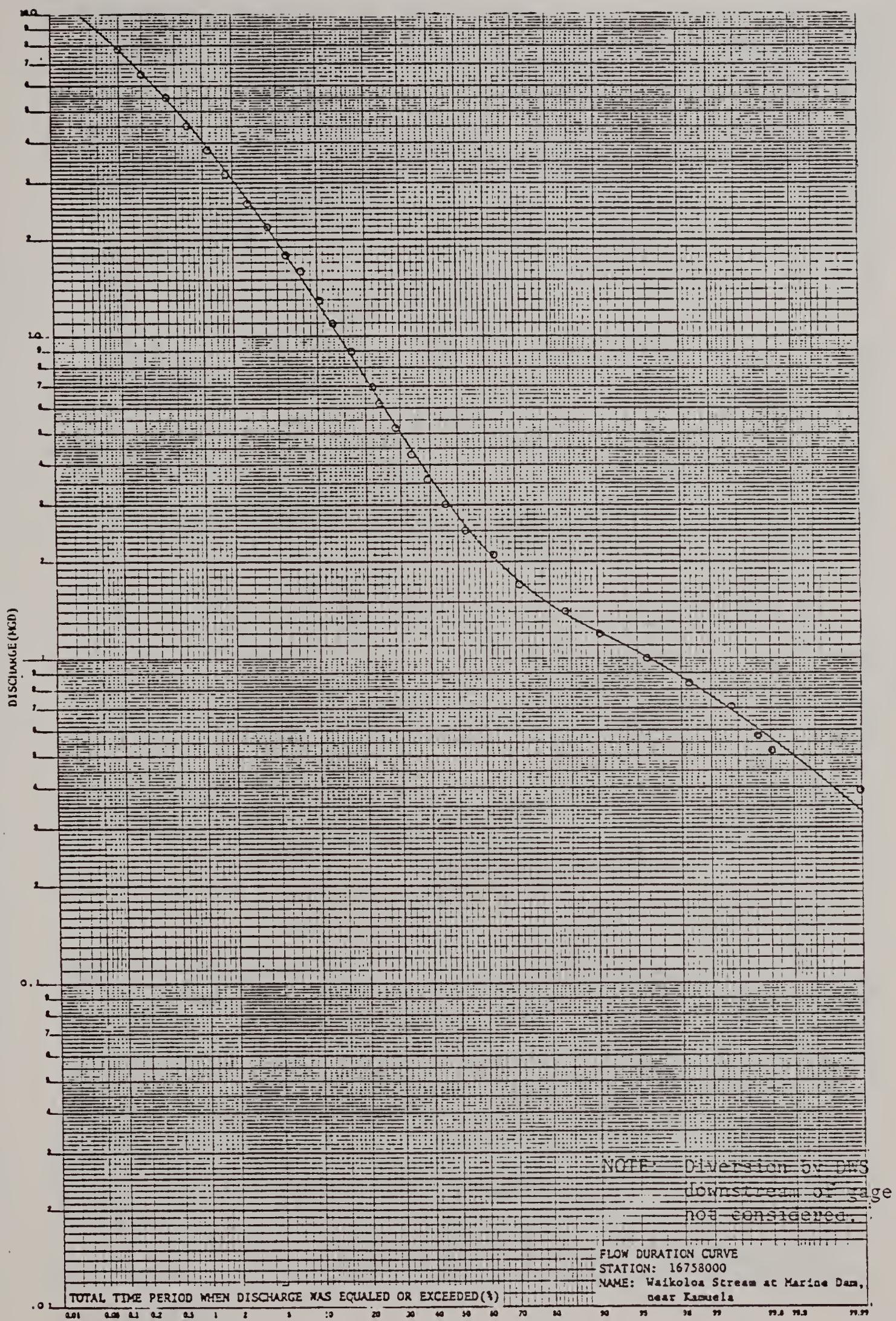


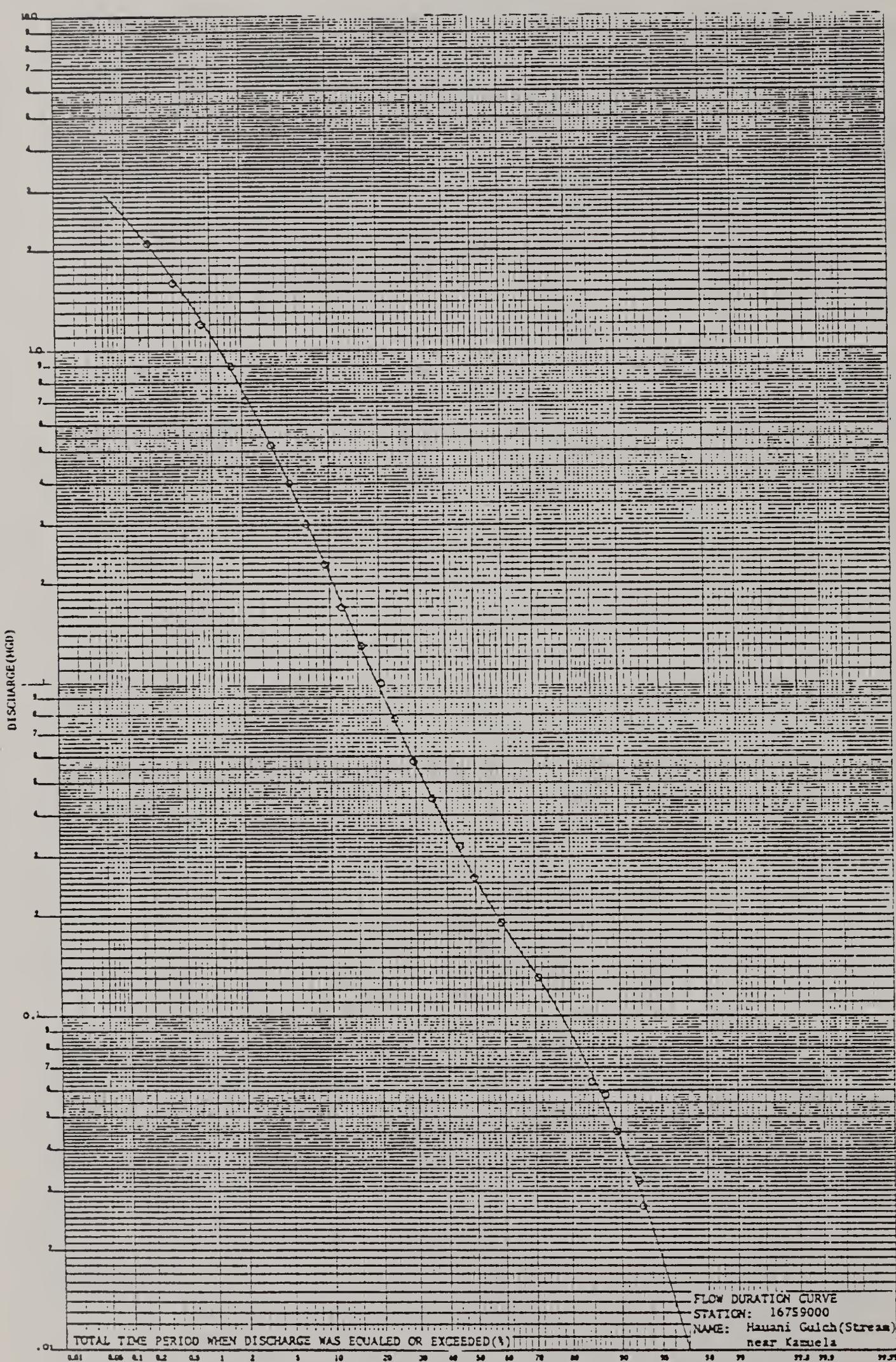






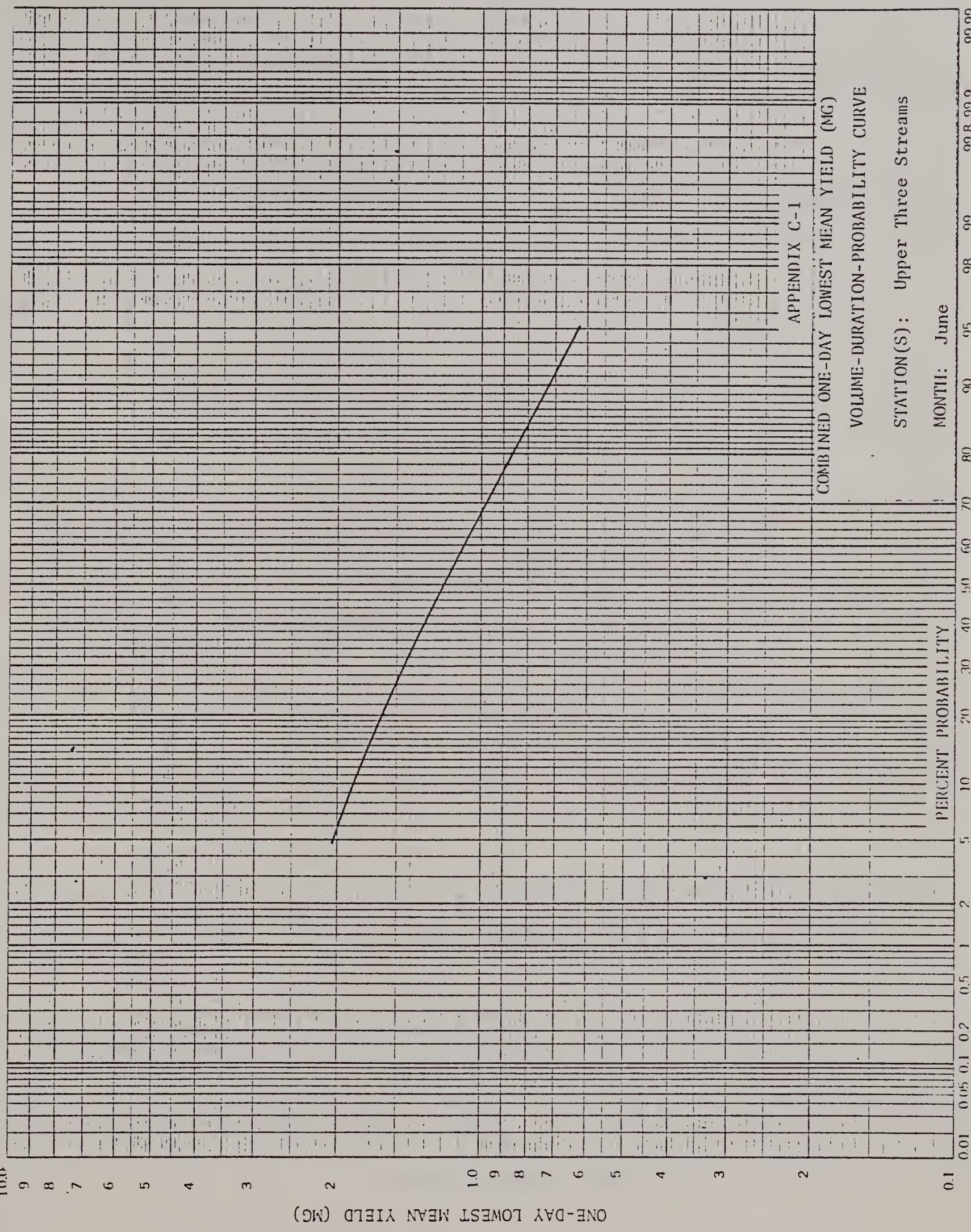




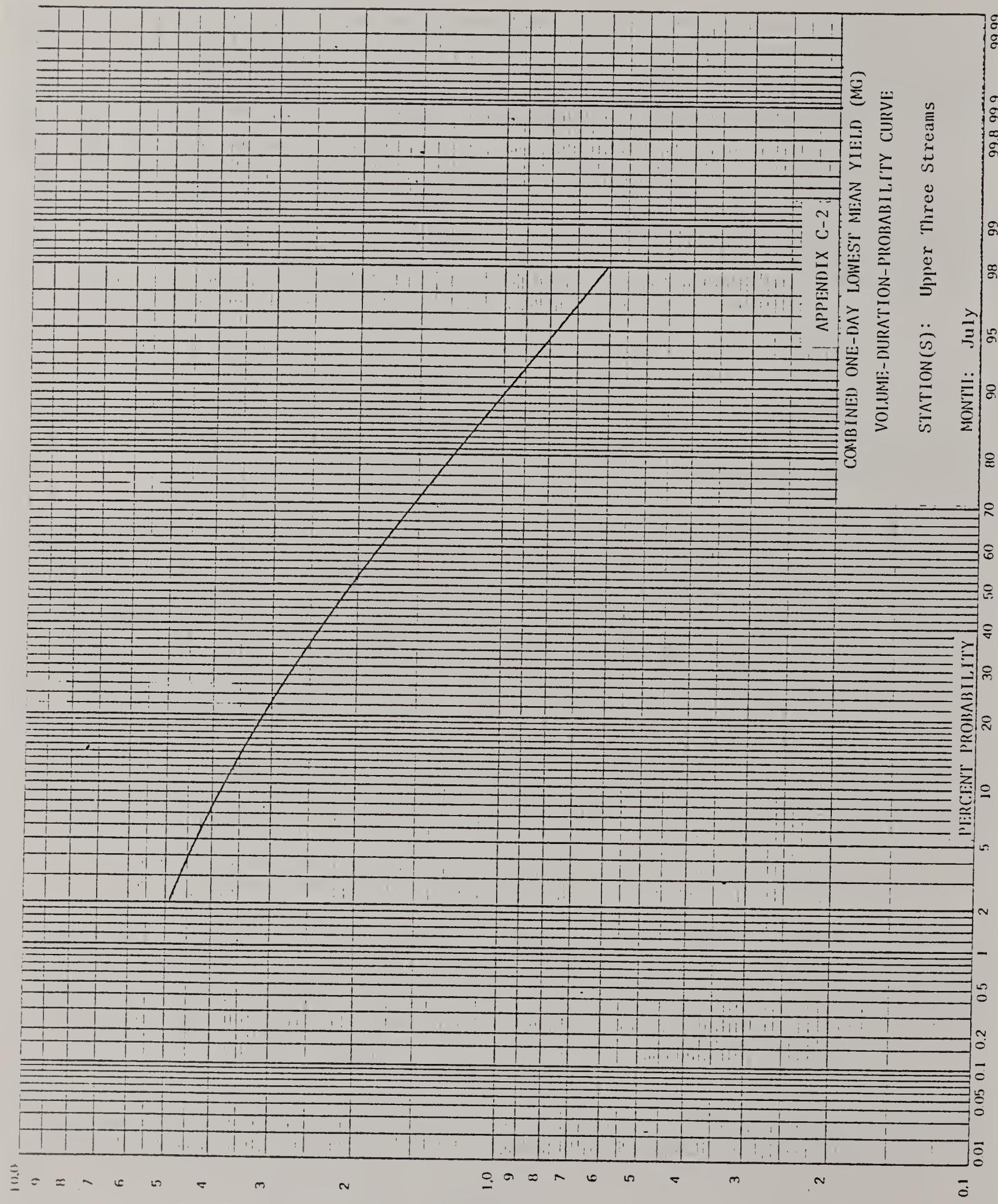


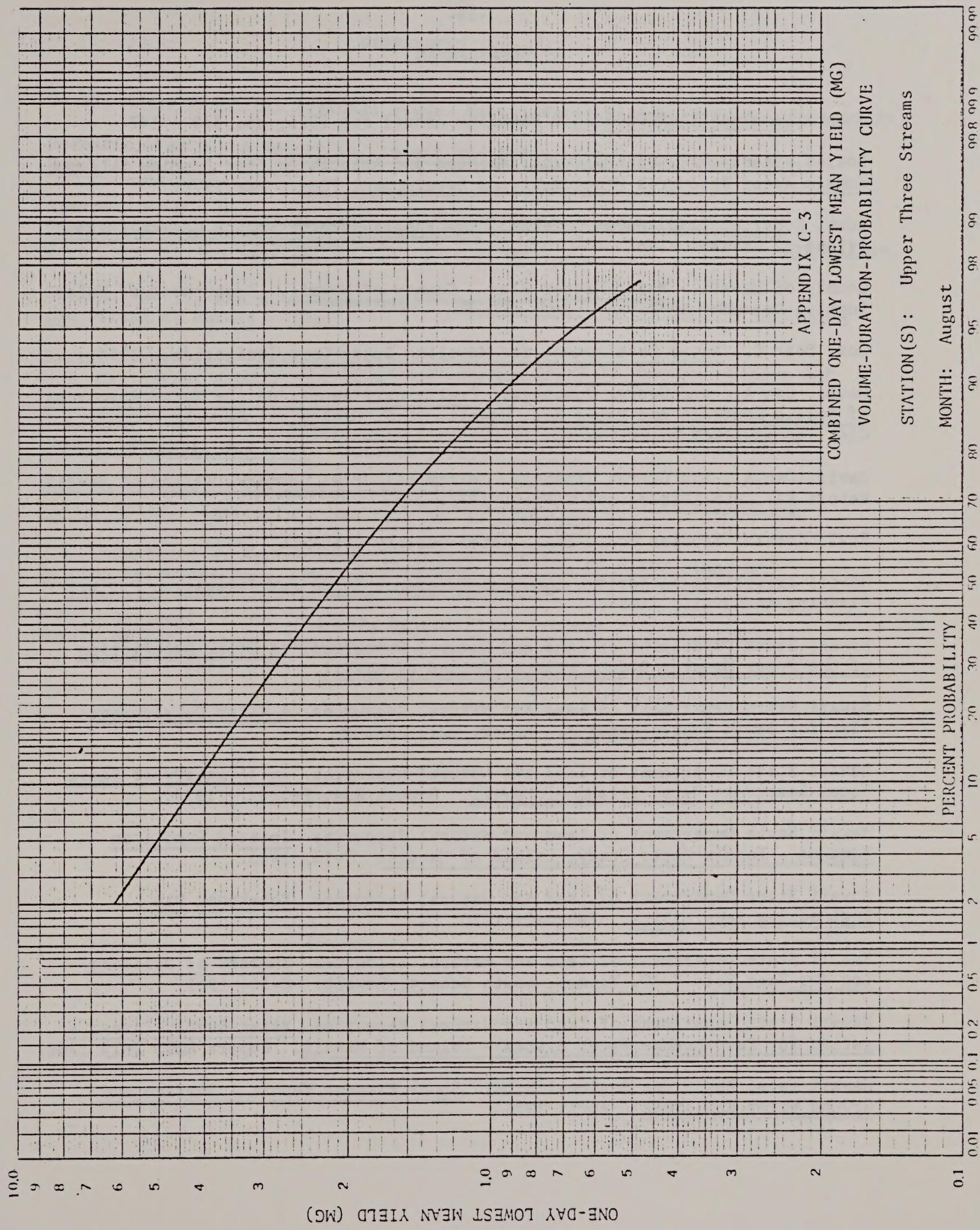
APPENDIX C

Volume - Duration - Probability Curves



ONE-DAY LOWEST MEAN YIELD (MG)





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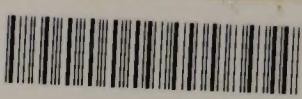
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